TALLINNA TEHNIKAÜLIKOOL
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Department of Materials and Environmental Technology

SMART TEXTILE SYSTEM PRODUCT DEVELOPMENT EXEMPLIFIED WITH A JACKET

INTELLIGENTSE TEKSTIILITOOTE ARENDUS MEESTE JAKI NÄITEL

MASTER THESIS

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AUTHOR’S DECLARATION

Hereby I declare, that I have written this thesis independently.

No academic degree has been applied for based on this material.

All works, major viewpoints and data of the other authors used in this thesis have been referenced.

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Tarkade tekstiilitoodete ohutuse ja standardite uurimine

Kolme jaki lõike arendus ja 3D visualiseerimine

Jakkide tehniliste kirjelduste ning õmblustehnoloogia välja töötamine

Esiknäidise õmblemine

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INTRODUCTION

Working in clothing industry has shown that mass-production of clothing has reduced the fitting standard. Likewise, the product's life expectancy is not the priority for the producers. Living in the era when recycling and ecological lifestyle is not only necessary but also trending, researching durable materials, a great fit and extra value for clothes is crucial.

The combination of textile and electronic components results in new challenges for sustainable product design. Electronic textiles (e-textiles) feature an integration of textiles with electronics and other high-tech materials. The ongoing innovation process of e-textiles holds opportunities to prevent future end-of-life impacts. Adding value to textile products could minimize the waste which is developed daily.

For this reason, this work is dedicated to develop a timeless men's jacket with extra value. The main objective of this work is to research the options already existing at the market for creating a smart textile system. Additionally, how affordable and easily obtainable the options are. Furthermore, are the options easy to integrate to the product. The main goal is to see the results with making the first prototype.

The work consists of research and experimental part. Research includes looking into smart textile options and different 3D CAD systems that are available on the market. Furthermore, the safety of e-textile options areinvestigated and effects of electronics used in this work are calculated. The experimental part includes conducting thorough product development process with the result of final specifications and technical drawings. Moreover, the patterns are made in Lectra Modaris program with the additional help of Modaris 3D Fit program. In the end, first prototype is made to see how the integration of electronics and textile product could look like.

1. PROCESS OF PRODUCT DEVELOPMENT

1.1 Quality Function Deployment

Quality Function Deployment is a structured approach to defining customer needs or requirements through questionnaire (Appendix 1) which in this case received 50 answers. It was important to translate them into specific plans to produce products to meet those needs. This understanding of the customer needs is then summarized in a product planning matrix or "house of quality" (Figure 1). These matrixes are used to translate higher level "what's" or needs into lower level "how's" - product requirements or technical characteristics to satisfy these needs [2]. Frequently, customers will try to express their needs in terms of "how" the need can be satisfied and not in terms of "what" the need is [2]. This limits consideration of development alternatives. Development and marketing personnel should ask "why" until they truly understand what the root need is. It is needed to breakdown general requirements into more specific requirements [2].

House of Quality's left column is then for customers needs. They can be evaluated for their importance which also helps to make choices in the end. The upper part (the "how" part) of the House of Quality is for technical requirements or also called parameters. They are written based on customers' needs but the difference is that they are measurable. The "roof" of the house is for determine if the technical parameters support or impede on another, therefore the relationship is marked with "+" or "-". If they do not affect each other at all, it is left blank. Inter-relationships in the middle part of the house are to evaluate how significant the customers' needs and technical requirements are to one another, hence the relationship is marked "Θ" if it is very significant, "O" if it is medium and "▲" if it is not significant. Then the right column of the house is for seeing how competitors' products meet customers' needs. They can be evaluated with grades 1-5, where 5 is the best and 1 is the worst. Finally, in the end, the bottom part of the house is for the results. Based on relationships, correlations and competitors scores, it can be seen what parameter is the most necessary and if anything could be cut or even added [2].

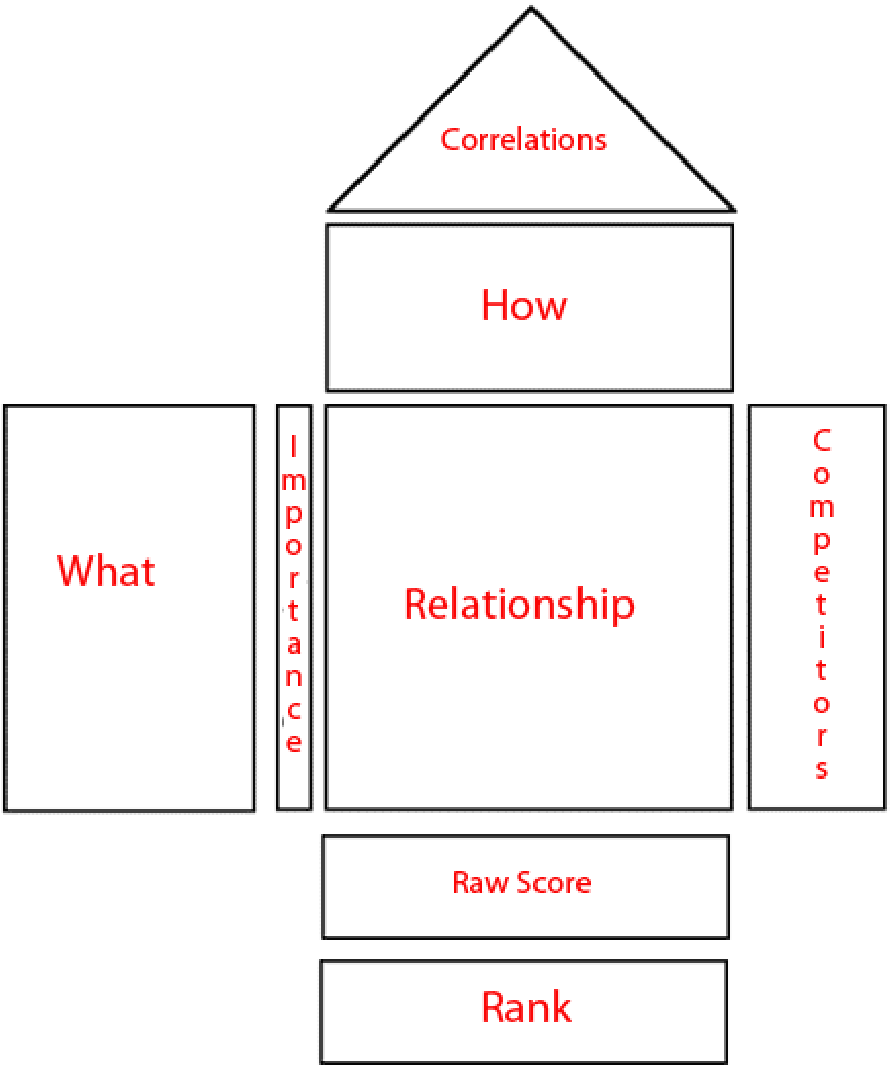


Figure 1. QFD House of Quality [2].

1.2 Questionnaire

First, it is possible to start the questionnaire (Appendix 1, Appendix 2). Questionnaire consists of mostly multiple choice questions with many answers. Also, there was always a possibility for open-ended answer. Questionnaire is the base for Quality Function Deployment its' output and analysis is the basis to figure out what materials and sewing technology should be used. 50 answers was received and the statistics are seen in Appendix 3APPENDIX 3.

1.3 Generating and choosing ideas

Looking through the received answers and seeing the customers' needs, it was possible to start generating ideas with the help of morphological table (Table 1). It is a table based on the function analysis. Left side of the chart lists the functions [2]. The right side lists different mechanisms which can be used to perform the functions listed are drawn [2]. It is a visual aid used to come up with different ideas.

Table 1. Morphological chart for generating ideas.

Men's jacket					
Function	**Variants**				
Model	Sport jacket	Light parka	Leather jacket	Letterman jacket	Wind jacket
Closing	Buttons	Zipper	Zipper and velcro	Zipper and buttons	Zipper and snapbuttons
Material characteristics	Water-resistant	Wind-resistant	Breathable	Not wrinkly	Thermal (clothing)
Existing details	Inner chest pocket	Pocket with zipper	Standing collar	Flap pocket	Lapel/rever collar

For choosing the best new ideas, qualitative research was used for. Qualitative research is best to uncover trends in thought and opinions and dive deeper into the problem. Qualitative data collection methods vary using unstructured or semi-structured techniques [3]. This case, additional questions and inquiries were made to customers.

1.4 First specification

Then it was able to work out the first concept, starting with defining the target group. Group consists of men who have their own income and do not live from one payday to another. Men who consider important to look good whether at they are work or spending free time outside home. Because of that they wish to invest in high-quality clothing but do not wish to have a lot of them. Customer's perfect jacket has a simple design and comfortable semi-slim fit. Also, the jacket should be easily accessible from stores or e-shops.

Additionally, the first specification could be made. That meant putting down customers' needs and technical requirements to House of Quality. They were seen on the left side and on the top part of the house. The needs and requirements are also seen in Table 2andTable 3. It was essential to define customers' needs more accurately and define the relevance of each one. Definitions of each need helped to create technical parameters, so the need could put into measurable quantities. Now, using the House of Quality, it was possible to put both of them together and compare and measure each parameter’s and need’s importance. The ‘roof’ of the house helped to define how each parameter could support or impede each other.

Table 2. Customers' needs

Nr	Customers’ needs	Relevance
1	Universal style	5
2	Esthetic look at work and on free-time	5
3	Simplicity of the product's style	5
4	Product's life expectancy	5
5	Presence of inner chest pocket	5
6	Water-resistant	5
7	Wind-resistant	5
8	Center-front closing with zipper and buttons/snap buttons	5
9	Breathable	5
10	Thermal clothing	4
11	Not wrinkly	4
12	Pockets with zippers	4
13	Product price 100 - 150 euros	4
14	Standing collar	3
15	Product price 50-99 euros	3
16	Product price 151-200 euros	3
17	Center-front closing with zipper	3
18	Rever/lapel collar	3
19	Center-front closing with buttons	3
20	Comfortable, quick and smooth way to put the product on	3
21	Long enough sleeves	3
22	Appropriate fit	3
23	Presence of a hood	2
24	Good ratio of the price and quality	2
25	Product length until hip	2
26	At least 4 pockets	2
27	Known manufacturer	1

Table 3. First specification, parameters of the product

Nr	Parameter	Relevance
1	Products function/purpose	5
2	Products esthetic look and simplicity	5
3	Product's life expectancy	5
4	Presence of inner chest pocket	5
5	Water-resistant main material	5
6	Wind-resistant main material	5
7	Center-front closing with zipper and buttons/snap buttons	5
8	Breathable main material	5
9	Thermal clothing	4
10	Not wrinkly main material	4
11	Pockets with zippers	4
12	Product’s price	3
13	Standing collar	3
14	Sleeves' length	3
15	Fit of the product	3
16	Presence of a hood	2
17	Length of the product	2
18	Number of pockets	2

1.5 Competitors’ research

When the customer’s needs and technical parameters were compared and evaluated, it was possible to research more men’s jackets and how the competitors through history have done them. Research showed many blazers that are made from wool, cotton and synthetic blend materials that are treated to be waterproof and breathable [4], [5], [6]. Water off a Duck’s Back clothes’ brand was to be found most similar to this work. Prices stayed around 100-200 euros. The brand was founded by Antonia Maybury from United Kingdom [6]. The brand manufactured sensible bicycle clothes which would look good in every situation. They even broadened their collection by making tailored coats and jackets with reflector elements [7]. Unfortunately, there were only some articles because the brand bankrupt and the homepage was suspended.

Additionally, some other jackets were found but not as similar to this projects jacket as they could or should be. For example, Hackett's City jacket or Jigsaw's Proofed Prince of Wales coat looked more like a shorter trench coat with extra neckline closure. The prices stayed around 300-600 euros. Also, Stutterheim's raincoats came up but these products, as the name states, are raincoats and would not be worn inside [4]. The prices stayed around 200-400 euros. Most similar jacket was Timberland's Mount Clay waterproof jacket with the price around 300 euros [5].

In local shops, no actual suit like jacket with coated fabric was found. Still, two jackets were compared: parka from Reserved shop with the price of 100 euros (Figure 2) and sport jacket from Timberland shop with the price of 290 euros (Figure 3). Competitors' evaluation is on the right side in the House of Quality. It needed to be compared based on customers' needs by evaluating them with grades 1-5, 5 being the best and 1 being the worst.

Figure 2. Reserved parka for competitors' analysis [11].

Figure 3. Timberland sports jacket for competitors' analysis [5].

1.6 Second specification

After this evaluation, the second specification (Table 4) could be made, based on the bottom part of the House of Quality. The values are based on standars seen in 'Unit' column or House of Quality results. Some technical parameters that could not be measured, e.g., esthetic look and functionality, were changed. They were divided by relevance to other parameters that support the value and result of these parameters. Therefore, esthetic look was divided between product length, breathable product, fit, sleeve length and non-wrinkly main material parameters. Functionality was divided between chest pocket number, water-resistant product, wind-resistant product, breathable product, thermal product and pockets number parameters. Finally, center-front closing with zipper and buttons parameter was divided between fit and water-resistant product parameter. Still, the final House of Quality for men's jacket is seen in Appendix 4 [2].

Table 4. Second specification

Nr	Parameter	Relevance	Value	Unit
1	Product's price	10,3%	125	Price, euros
2	Water-resistant product	9,27%	5	ISO 2281 water resistance testing of a watch, atmospheres (atm)
3	Fit	8,97%	Semi-slim	Pattern type
4	Thermal product	8,12%	-	ISO 5085 Textiles - Determination of thermal resistance, m2·K/W
5	Breathable product	8,04%	500	g/m^2/24hrs, MVT (Moisture Vapour Transmission)
6	Product's length	6,92%	80	Length, cm
7	Pockets number	6,72%	5	Number
8	Wind-resistant product	6,22%	4	Cubic Feet per Minute (CFM)
9	Life expectancy	6%	5	Number of years
10	Sleeve length	5,82%	65	Length, cm
11	Non-wrinkly main material	5,72%	Polyester	Fiber type
12	Pockets with zippers number	5,1%	2	Number
13	Chest pocket number	5,02%	1	Number
14	Detachable hood option	4%	0	Number
15	Collar type	3,9%	Standing	Pattern type
		100		

Also, based on the results, it was possible to create the first updated product's technical drawings (Figure 17, Figure 18, Figure 19). Primarily, for trying out sewing technology and the best way to make the design happen, one jacket was made (7.3Prototype development). Therefore, it was possible to try out what would be the best solution to go on.

2. SMART TEXTILES.

2.1 Smart textiles

Basis of the theoretical part is knowledge about smart textiles, especially about electronic textiles or so called e-textiles. There is no exact definition for e-textile but most conclusive would be that electronic textiles (e-textiles) are a novel type of high-tech products resulting from the integration of electronics and technical textiles or clothing. [1]. E-textiles are fabrics that feature electronics and interconnections woven into them, presenting physical flexibility and typical size that cannot be achieved with other existing electronic manufacturing techniques. Components and interconnections are intrinsic to the fabric and thus are less visible and not susceptible of becoming tangled or snagged by surrounding objects. E-textiles can more easily adapt to fast changes in the computational and sensing requirements of any specific application. The vision behind wearable computing foresees future electronic systems to be an integral part of our everyday outfits. Such electronic devices have to meet special requirements concerning wearability [12]. With IoT or so called Internet of Things emerging with Windows 10 operation system, electronic and smart textiles are developed daily.

Additionally, chemistry has been used to give extra credit to textiles. Most used techniques is surface treatments with hydrogels. By treating the textile in different ways, it could become responsive to UV-radiation, heat etc. by using chemically treated textiles, the term ‘e-textile’ becomes useless and ‘smat textile’ more current.

2.2 Realization techniques for smart textiles with electronics

2.2.1 Conductive fibers and treated conductive fibers

Electrically conductive fibers can be classified into two general categories: those that are naturally conductive and those that are specially treated to create conductivity. Naturally conductive fibers or metallic fibers are developed from electrically conductive metals such as ferrous alloys, nickel, stainless steel, titanium, aluminum, copper. Treated conductive fibers can be obtained from conductive metal or carbon powders which are used in the production process. In this method, percentage of used powder has to be investigated in order to reach conductivity threshold through surface contacts between particles. Another method for obtaining conductive fibers is coating them with certain metal salts like copper sulfide and copper iodide, as they are easily processable using ordinary textile technology. However, only low conductivities can be gained. Some disadvantages of conductive fibers like their brittle property that can abrade the spinning equipment, their high price, five times heavier than some textile fibers, and their undesired touch of produced fabrics caused more attention to turn towards carbon fibers [13].

Conductive fibers (Figure 4) were mainly used in technical areas: clean room garments, military apparel, medical application and electronics manufacturing. Textile structures that exhibit conductivity or serve an electronic or computational function are called electro-textiles. They can have a variety of functions, like antistatic applications, electromagnetic interference shielding (EMI), electronic applications, infrared absorption or protective clothing in explosive areas. For example, company Swiss-Shield® (Flums, Switzerland) specializes in producing metal monofilaments which are incorporated into base yarns like cotton, polyester, polyamides and aramides. The metal monofilaments are made out of copper, brass, bronze, silver, gold, aluminum, for instance[12].

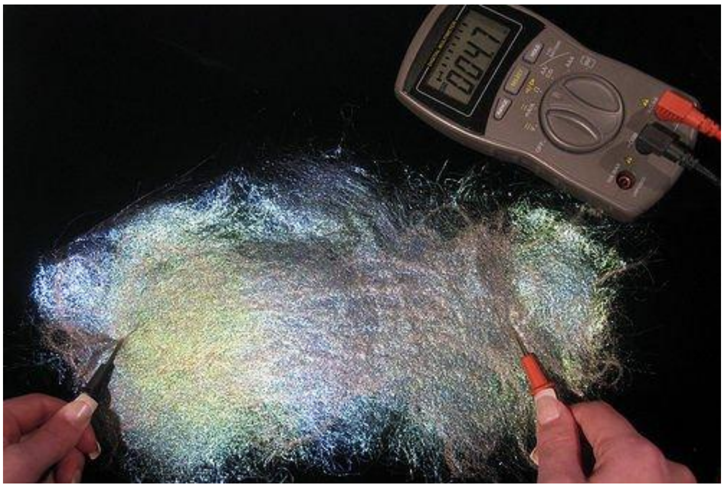


Figure 4. Conductive fibers [12].

2.2.2 Conductive yarns

Conductive yarn can be produced by conductive polymer ormetallic fibers which are spun with natural or standard syntheticfibers or are created by wrapping and can be used in the normaltextile processes of embroidery, knitting, and weaving. Very small quantities of inorganic fibers are spun into staple yarns. Asbestos is used minimally because of well-reported associated health problems; glass, basalt, and metal fibers are used largely in filament form or as nonwovens, but small quantities of staple yarns are produced from metal fibers on conventional spinning systems and have applications in the areas of conductive fabrics and some protective clothing [13].

The copper thread makes over the silk yarn into a highly conductive yarn with a silk core (Figure 5). The physical characteristic of the silk core provide the total yarn high tensile strength and a tolerance for high temperatures, permitting it to be sewn or embroidered on industrial machinery without being damaged. Additionally, these properties make metallic yarns very talented for mass producing interactive electronic textiles [13].

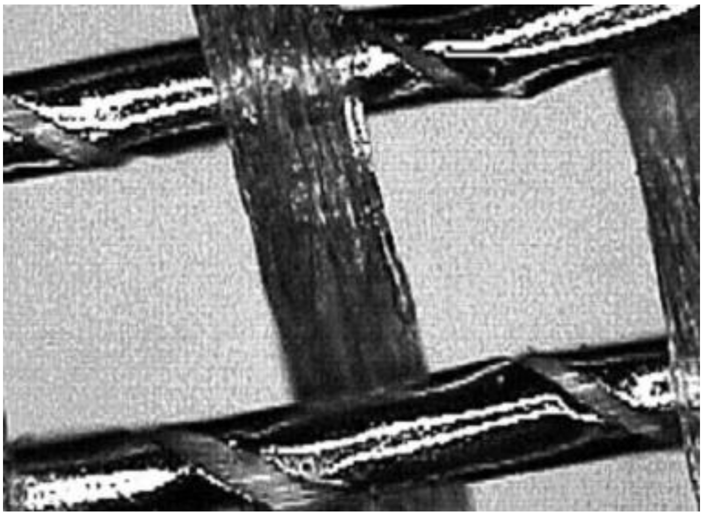


Figure 5. Micrograph of metallic silk organza [13].

2.2.3 Conductive polymers

Materials can be generalized into three groups in terms of electrical conductivity: insulators, semiconductors and conductors. Conductive polymers are in the group of semiconductors. Electronic energy is important in determining the electric conductivity of materials [3]. Today, a wide variety of conducting polymers are available, more popular kinds is shown in Figure 6. In order for polymers to be electronically conductive they must possess not only charge carriers but also an orbital system that allows the charge carriers to move. The conjugated structure can meet the second requirement through a continuous overlapping of S-orbitals along the polymer backbone [13].

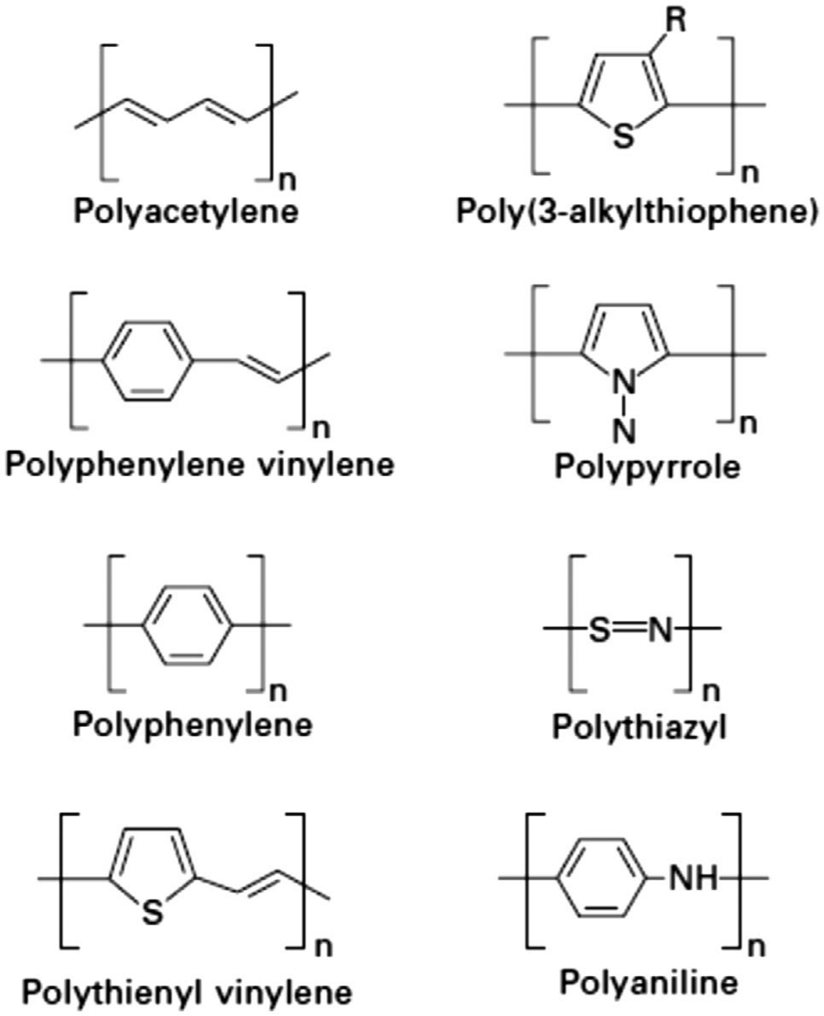


Figure 6. Chemical structure of more popular electrically conductive polymers [13].

In conductive polymers, there are no holes or free electron formation in the conduction bands, unlike crystalline semiconductors. The difference from inorganic semiconductors lies in the structure of the polymer backbone, which is deformed after the polymer is oxidized or reduced by the dopants. In the doping process, radical cations or anions formed on the polymer backbone are called “polaron”. A polaron has two defects: charge and defect. In this concept, conducting polymers can be classified into two main groups: degenerate ground state and non-degenerate ground state. The main difference between these polymers is apparent when they are subsequently charged. When conducting polymers with degenerate ground states are charged subsequently, a second polaron is formed.Conductive polymers are used in many fields, like microelectronics, antistatic packaging, thus, including also e-textile filed, where they are screen printed on the textile or used in yarns [14].

2.2.4 Conductive fabrics

There are different ways to produce electrically conductive fabrics (Figure 7). One method is to integrate conductive yarns in a textile structure, e.g., by weaving. However, the integration of conductive yarns in a structure is a complex and seldom a uniform process as it needs to be ensured that the electrically conductive fabric is comfortable to wear or soft in touch rather than hard and rigid. Conductivity can be established with different thread types. However, woven fabric structures can provide a complex network that can be used as elaborated electrical circuits with numerous electrically conducting and non-conducting constituents, and be structured to have multiple layers and spaces to accommodate electronic devices[2].

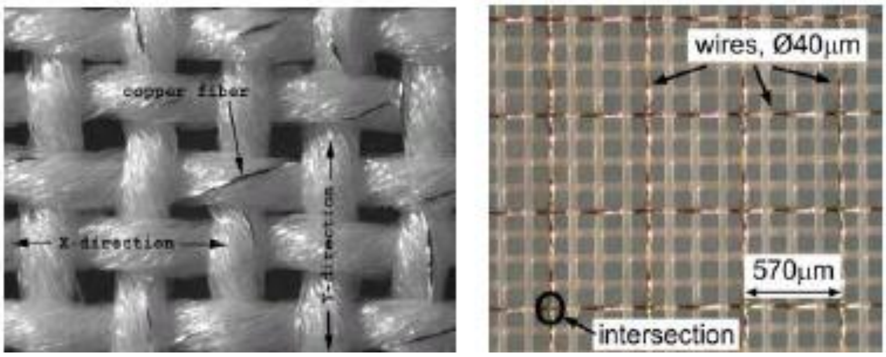


Figure 7. Conductive fabric from copper and polyester yarns [12].

For example, British company Baltex (Ilkeston, UK) uses the knitting technology to incorporate metal wires in textile structures. Their fabrics, which they commercialize under the name Feratec®, can be used mainly for two purposes, namely heatable textiles and electro-magnetic shielding materials. Also, American company Thremshield LLC (Niagara Falls, NY, USA) produces metallized woven nylon fabrics in different shapes and profiles. The metals they use are silver, copper or a combination of copper and nickel [2].

2.2.5 Conductive inks

Interactive electronic textiles can also be produced by using conductive inks (Figure 8). First of all conductive inks must contain an appropriate highly conductive metal precursor such as Ag, Cu, and Au nanoparticles and a carrier vehicle. Most of them are water based: water is the main ink component and to limit contaminants, it must be as pure as possible. These specialized inks can be printed onto various materials, among them textiles, to create electrically active patterns[12].

Elastic textile materials have showed not to be suitable flexible substrates for thin film deposition. The low stiffness conducts to localized elongations of the thin deposited films making the samples non-conductive. It is desirable that electronics in textiles conform to the inherent textile properties which are flexibility and conformability. Both of these can be fulfilled by the PVC coated materials [13].

Screen printing also makes integration with planar electronics simpler than with conductive yarn systems. There are several technologies that can print conductive material on different substrate. Sheet-based inkjet and screen printing are best for low-volume, high-precision work [12].

For inkjet printing, the inks should respect the following requirements:

- high electrical conductivity;
- resistance to oxidation;
- dry out without clogging the nozzle during printing;
- good adhesion to the substrate;
- lower particle aggregation;
- suitable viscosity and surface tension.

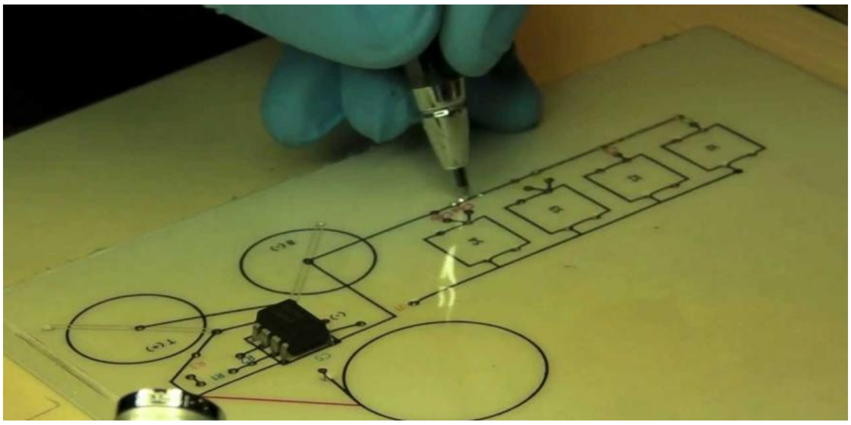


Figure 8. Drawing with conductive ink [12].

For example, The National Textile Center of the North Carolina State University (Raleigh, NC, USA) is currently working on a project dealing with ‘Printing Electric Circuits on Non-Woven Fabrics‘ used to produce a prototype for a physiological monitoring garment that measures ECG, heart-rate, respiration and temperature [12].

2.2.6 Conductive materials as sensors

Conductive textiles that change their electrical properties as a result of the environmental impact can be used as sensors [12]. Various kinds of sensors can be integrated to the fabrics which make it intelligent in order to be used in different fields such as ECG, electromyography (EMG), and electroencephalography (EEG) sensing, fabrics incorporating thermocouples can be used for sensing temperature, luminescent elements integrated in fabrics could be used for biophotonic sensing, shape-sensitive fabrics can sense movement, and can be combined with EMG sensing to derive muscle fitness. Carbon electrodes integrated into fabrics can be used to detect specific environmental or biomedical features such as oxygen, salinity, moisture, or contaminants [13].

Typical examples are textiles that react to deformations such as pressure sensors, stretch sensors and breathing sensors. There are different types of sensors [12]:

1. Stretch sensors (Figure 9) - mostly used for sensing and monitoring body parameters, as the textile is in contact with the skin over a large body area. This means that monitoring can take place at several locations on the body. For instance, these sensors can be used for determining: heart rate, respiration, movement and blood pressure.
2. Pressure sensors - commonly used either as switches and interfaces with electronic devices or also to monitor vital signs of the user.
3. Electrochemical Sensors - flexible and textile-based screen printed electrochemical sensors may be candidates for non-invasive monitoring, but these devices cannot easily be attached to the body and in particular to the skin.

Figure 9. Sensors in the glove detect the wearer's hand movements [12].

Yongsang Kim, in 2010, applied a P-FCB (see Heading 2.2.7) technology to implement a complete system for continuous healthcare by sensing the humidity. It is composed of a fabric capacitor sensor input, a controller system-on-a-chip, and an LED array display is implemented on the fabric. The humidity has a great effect on the capacitance values of all types of capacitors. The capacitance value goes up when humidity increases. When a water drop is detected by fabric sensor electrode, the controller chip senses the variation in the capacitance value. Then, the LED light is on when the capacitance value is over the programmed threshold value [13].

2.2.7 Planar Fashionable Circuit Board (P-FCB)

The P-FCB or PlanarFashionable Circuit Board (Figure 10) is one of the new technologies allowing implementation of a circuit board on a plain fabric patch for wearable electronics applications. P-FCB is made by screen printing technology and investigated electrical characteristics of passive devices such as resistor, capacitor, and inductor [13]. It features a soft and flexible impression just as normal clothes. The P-FCB substrate is fabricated using woven fabrics. The planar electrodes are deposited on the fabric patch directly by silk screening of conducting epoxy or by gold sputtering [12].

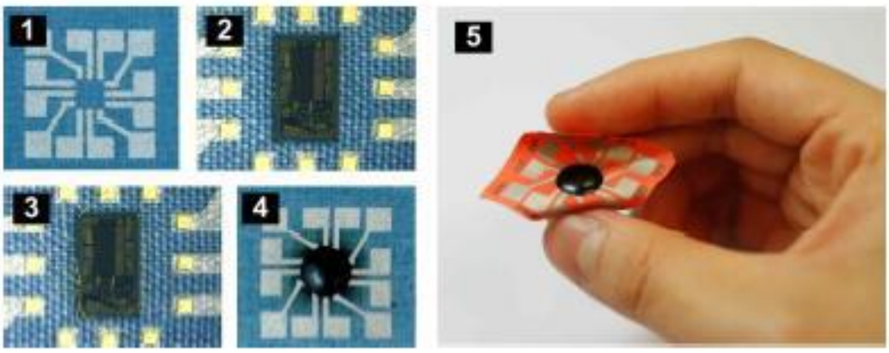


Figure 10. Single-layered P-FCB system manufacturing process [12].

2.2.8 Wearable Antenna

A wearable antenna (Figure 11) is thus the bond that integrates clothes into the communication system, making electronic devices less obtrusive. To achieve good results, wearable antennas have to be thin, lightweight, low maintenance, robust, inexpensive and easily integrated in radio frequency (RF) circuits. Planar structures, flexible conductive and dielectric materials are specific requirements for wearable antennas. In general, textiles present a very low dielectric constant that reduces the surface wave losses and increases the impedance bandwidth of the antenna. Therefore it is important to know how these characteristics influence the behavior of the antenna in order to minimize unwanted effects. For example, Patria (Halli, Finland) is a company with expertise in textile antenna design. It develops textile antennas composed by conventional or industrial fabrics, and typically conductive antenna parts are made out of modern conductive fibers [12].

Figure 11. Textile antenna made from inox thread [12].

2.2.9 Hydrogels

The functionality of textile fibres and fabrics can be enhanced considerably by chemical finishing treatments that are responsive to changes in the conditions of their environment. Responsive surface treatments are based upon hydrogel chemistry. Hydrogels are 3D network structures of hydrophilic polymers and can be natural or synthetic in origin. The polymers are insoluble in water but, because of their hydrophilic nature and ability to swell, they are extremely absorbent. Due to their high water content they are soft and flexible, which makes them suitable for biomedical applications. The ability of hydrogels to change their physico-chemical character in response to a change in the external environment has led to them being referred to as “smart” gels[15].

Still, hydrogels have bulky 3D structures and their application to textiles is problematic in that they can be slow to respond to a stimulus. In addition, they may affect the inherent properties of the textile, in terms of strength, flexibility and handle, etc. These difficulties can be overcome, however, if they can be applied as microgels, which can be applied as very thin layers on textile surfaces, and their large surface area per unit mass gives them quick response times to stimuli.There are available temperature–responsive, pH-responsive, photo-responsive (UV radiation), bio-responsive (e.g. for insulin release) and dual stimuli-responsive hydrogels [15].

Smart polymers that show capabilities of responding to the external stimuli have significant potential applications in various fields. Stimuli-sensitive fabric can be used in deodorant fabrics, nutrient or drug released medical textile, cosmetic textile and oil absorbing fabrics that are used to protect the environment against pollution. With the development of textile manufacturing in nanoscale, it seems that, using of stimuli-responsive nano hydrogels on nano fibers can lead to make remarkable properties in the next generation of textiles [16].

2.2.10 3D printing

The 3D printing (3DP) process begins with designing the product using CAD software, typically a 3D modeling program. Through the adjustment of computational algorithms, designs can be altered to make improvements or include specific size parameters for individual consumers. The data from the file are then communicated to the printer, which develops the 3D product by each divided layer. After the object is printed, it may need sanding and polishing to improve the surface finish and diminish the look of print lines. Figure 12 outlines the general design and production process of 3DP methods[18].

Five possible 3DP methods most applicable to fashion products: Stereolithography (SL), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM), PolyJet, and binder jetting. There are benefits and challenges associated with each method that must be considered[18]. There is also Selective Laser Melting (SLM) which is basically the same as SLS but go one further, by using the laser to achieve a full melt, meaning the powder is not merely fused together, but is actually melted into a homogenous part [19].

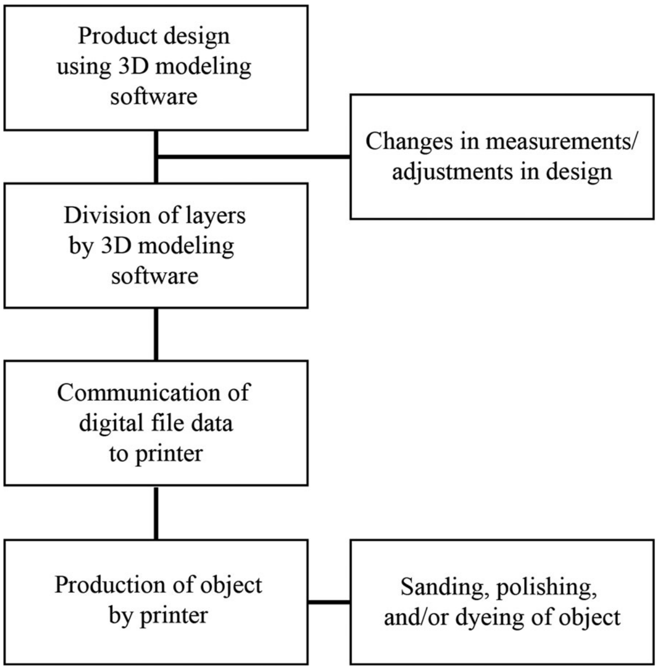


Figure 12. General design and production process of 3DP methods [18].

SL uses a photopolymer resin, which is a liquid plastic, and an ultra-violet (UV) laser to cure and harden individual layers to form objects. Typically, products print within a few hours, as the laser beam is able to scan as fast as 889 centimeters per second. Also, SL is relatively user-friendly, allowing inexperienced designers to create detailed pieces with a high-quality surface finish. However, a disadvantage of SL is that it requires support rafts, which secure the product to the building platform during production and are manually removed after completion. Other disadvantages include the print material cost and lack of color variety. However, smaller, less expensive SL printers are being introduced [18].

SLS utilizes high-powered lasers to fuse tiny particles of powder from polymers, such as glass, plastic, metals, ceramics, or nylon, into a completed 3D product. A benefit of SLS is that it allows designers to create delicate, yet highly functional and durable products with a wide variety of available materials. Also, SLS does not use support rafts, requiring less sanding of the object after it is printed. However, a disadvantage of SLS is that it does not produce a high-quality surface finish compared to SL [18]. As said earlier, SLM is basically the same but additionally melts the particle to have more even result[19].

FDM is commonly used, as it is relatively affordable and offers a variety of low-cost desktop printers. Materials used generally consist of wax, metals, and ceramics. FDM also requires support rafts, which must be mechanically broken off or dissolved in detergent. Researchers have found FDM capable of printing flexible, glossy, lace-like fabrics with soft PLA polymers. ABS materials allow for additional movement, as they are strong and flexible, making them ideal for creating joints. However, disadvantages of FDM are visible seam lines between layers and delamination from temperature changes[18].

PolyJet 3D printing is a technology that is similar to inkjet printing. However, instead of jetting inks on to the paper, PolyJet printers deposit curable liquid photopolymer layer-by-layer on top of the building platforms to create 3D components. Furthermore, it can be used to make smart textile products [17]. PolyJet allows multiple materials to be deposited in a single layer. Rigid parts and connective joints can be printed together at one time. PolyJet offers a high-quality surface finish, and is one of the fastest 3DP methods. However, PolyJet requires support rafts that must be mechanically removed. In addition, exposure to ambient heat, humidity, or sunlight can lead to dimensional change of the product [18].

Binder jetting uses glue, or binder, to bond successive layers of powder material together to form a 3D product. Binder jetting bonds single layers within seconds and does not require support rafts, making it the fastest 3DP method. Another benefit of binder jetting is that it is the only 3DP method that is able to print in multiple colors simultaneously, as the single monochrome inkjet head is substituted for a four or five color head. However, binder jetting usually builds weaker products and may provide an uneven surface finish [18].

Haute couture fashion designers are also using 3DP to communicate ways emerging technology can be used for innovative fashion design. London-based designer, Catherine Wales, displayed her Project DNA collection of 3D printed corsets, masks, and helmets at the Arnhem Mode Biennale in the Netherlands. Wales used a combination of engineering programmes to develop complicated joints and creative design software to develop sculptural forms. The accessories were printed in nylon using SLS to provide flexibility for the joints. Mass-market fashion brands are also using 3DP to produce customized products for consumers. San Francisco-based Continuum allows consumers to purchase their N12 bathing suits, made to order via measurements entered into the retailer’s website. Continuum has partnered with 3DP company, Shapeways, to develop these customizable products. Continuum prints the bathing suits using SLS and a solid nylon material called Nylon 12, giving the products a fabric-like feel with waterproof properties [18].

While there are a variety of trade publications that discuss how general 3DP methods are used by designers and companies in the fashion industry, there is a lack of scholarly information about 3DP for the fashion industry. Future research could include case studies about designers or fashion companies and how they use 3DP to create products [18].

2.2.11 Lilypad Arduino

The most commercial e-textile application opportunity is Lilypad Arduino (Figure 20). Lilypad is a set of sewable electronic pieces designed to help you build soft interactive textiles. A set of sewable electronic modules–including a small programmable computer called a LilyPad Arduino – can be stitched together with conductive thread to create interactive garments and accessories. LilyPad was designed by LeahBuechley and commercial version of the kit was collaboratively designed withSparkFun Electronics [20]. The LilyPad is an open-source hardware (OSH) project. This means schematic and board layout files are released under the creative commons license for people to copy for free and repurpose the designs as long as the previous work is cited [22].

To build an e-textile, the user sews modules together. The “petals” on each flower-like module can be sewn through with conductive thread that creates both physical and electrical connections, attaching components to a design’s background fabric and providing buses for power and data transmissions between pieces. The microcontroller (Figure 13in C can be programmed with the popular open source, free Arduino programming environment, downloading programs to the board via a USB-to-serial adapter [21].

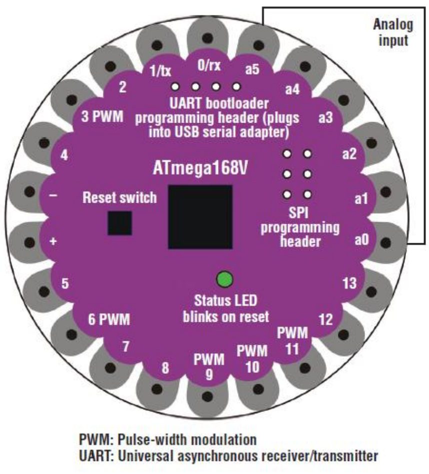


Figure 13. Diagram of the Lilypad microcontroller module [21].

3. STANDARDS, SAFETYAND ENVIRONMENT IMPACT

3.1 Standards for regulating e-textiles

The smart textile market is still small, most products are in prototype phase. Still, some smart textile goods are already available. For example, Google has several collaborations with different brands, e.g. Levi [23], to start producing smart textile products. 'Smart' or 'intelligent' textile could mean different things to different people. Therefore, European Committee for Standardization has compiled a technical report (CEN/TR 16298:2011) to define thesekinds of products and to help to guarantee their safety. Based on that smart textile system is a textile system that exhibits intended and exploitable responses as a reaction either to changes in its surroundings/environment or to an external signal/input. It also stresses that textile system and textile product may be interchangeable in many cases [24].

The technical report helps to characterize an intelligent textile system with a flow chart and brings a lot of examples to help verify. The report includes also phase change materials, geotextiles and other possibilities for smart textiles, e.g. optically conductive or fluorescent textiles materials. Still, it only gives guidelines and just defines the concept. The main reason is that the synergies between so many options cannot be foreseen, hence, the difficulties. Overall, it is the first step and in the future there probably will be several standards to define as many and different products as possible [24].

3.2 The e-textile applications' impact on human bodies

Smart textile systems may also be referred to as "wearables" or wearable electronics, meaning they can be used all the time no matter the place. Electromagnetic field is the term used to describe combined electric and magnetic fields. Electric fields exist whenever electric charges are present, i.e., whenever electricity or electrical equipment is in use. A magnetic field is produced when electrical current flows in a conductor with magnetic field lines perpendicular to the current flow. Therefore, all wearable electronics, including cellulartelephones, come with electromagnetic field[25].

Electromagnetic radiation is the term used to describe electromagnetic energy radiating away from its source. Electromagnetic radiation can be described as ionizing versus nonionizing radiation. Ionizing radiation consists of very short wavelengths, such as X-rays, which have enough power to move electrons off their nuclear orbits. In contrast, non-ionizing radiation consists of longer wavelengths with less power and is incapable of moving electrons off their orbit around the nucleus. Electromagnetic fields are characterized by wavelength, frequency, and field strength. Radiofrequency energy, defined by a frequency range between 0 Hz to 450 MHz, is emitted by sources including MRI, electrosurgery, and radio and television broadcasting. Cellular telephones, microwave ovens, and radar transmitters typically emit microwave energy, defined by a frequency range between 450 MHz to 12 GHz [25].

European Union has limited the electromagnetic fields to public exposure between 0-300 GHz [26]. Keeping that in mind, all the above should be safe and most scientists, engineers, and health care agencies take the stance that wearable devices, emit such low levels of EM radiation that they pose no health risks at all. Still, EM radiation can also affect cells from an electrical perspective. Small variations in electrical fields can disrupt the firing of neurons in the brain [27]. Most thorough research to determine the health risks of wearable technology is about pacemakers or Cardiovascular Implantable Electronic Devices (CIEDs). Most recent research focuses on whether other technology, like cellular telephones, affects the CIEDs. Results are negative, therefore, that supports the idea that health risks are extremely low [25].

Center of Disease Control and Prevention confirms that there is no scientific proof that cellular telephones cause cancer, let alone wearable computers, like smart watches. Additionally, they confirm that wearable technology emit non-ionizing radiofrequency which is a lot weaker than ionizing, e.g. X-rays. Figure 14 shows the electromagnetic spectrum. Cellular telephones are on the same level as microwave ovens, thus, on the lower energy side. Accordingly, the wearable technology is the even safer. In this work, the wearable computer does not upload or download information to another device through air, therefore, it is safer than cellular telephones or other wearable technology[28].

In this work, the microcontroller with sensors and conductive thread give out only direct current. That means the device will not make waves of different frequencies. Thus, the electromagnetic field is still there but stable. Earth’s magnetic field ranges from 25-65 μT and according to World Organization of Health (WHO) the allowed electromagnetic field exposure is 100μT [28]. The calculated magnetic field around the integrated microcontroller is 2μT. therefore, it could be concluded that the integration is safe.

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi 10^{-7} \times 10^{-2}}{2\,\pi\, 10^{-3}} = 2\mu T \qquad (1)$$

Where$B$ is magnetic filed (T),r is the distance from the wire (m), I is the current (A), μ_0= $4\pi 10^{-7}$ Tm/A.

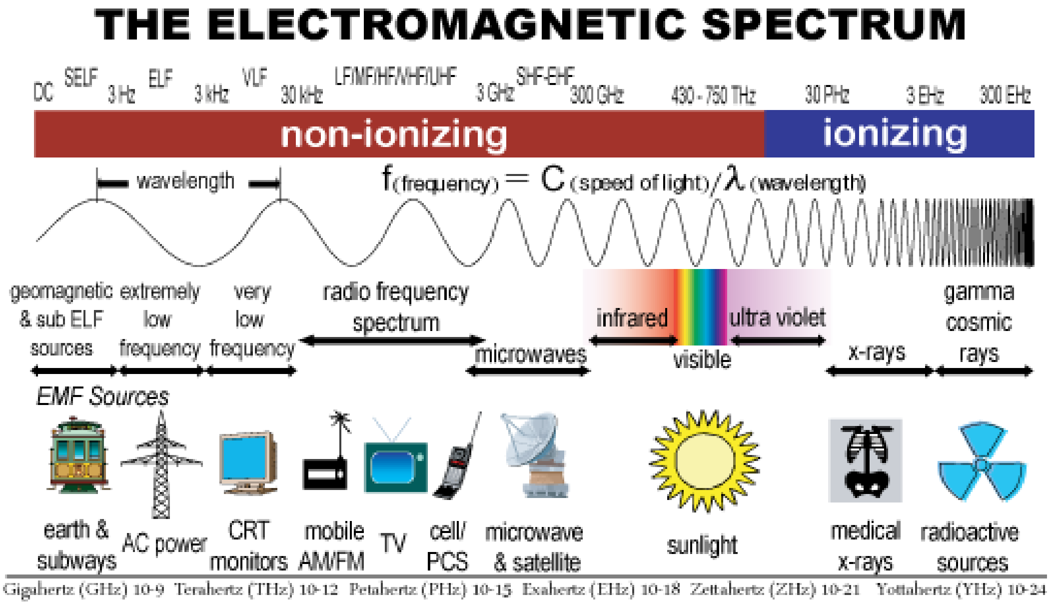


Figure 14. Electromagnetic spectrum [30].

3.3 Environmental impact of e-textiles

Talking about smart textile systems, it is important to understand that it is not just textile anymore. E-textiles may entail adverse environmental impacts because of its disposal after the end of their useful product life. High-tech products usually turn to waste because they are replaced by newer models after a relatively short service life. It may be even worse within the textile products because of fleeting fashion trends. Though, the idea behind smart textile products are that they have higher value and, therefore, should last longer, there are several reasons why e-textile waste could be hard to manage. Large mass flow of waste e-textiles could be expected with this type of smart textile research and development field growing rate. Also, textile-embedded electronic components contain small amounts of scarce materials, such as silver, gold, and rare earth elements, which are scattered across large textile surface areas and hard to recover [1].

Still, there are already several old technology collecting points in EU countrieswhere e-textile components could be taken there after end of their useful product life. Additionally, the International Organization for Standardization has issued a technical report (ISO/TR 14062:2002) that outlines a systematic procedure for integrating environmental aspects into product design and development processes. The document predicts the environmental issues before they emerge [1].

4. 3D CAD SYSTEMS FOR CLOTHING INDUSTRY

Today's clothing industry increasingly prefers to use computer-aided design (CAD) techniques for both fashion design and pattern creation as it offers greater efficiency and time-saving solutions to many complicated tasks as well as facilitating Internet-based communication amongst designers, manufactures and retailers. Two-dimensional (2D) graphics software packages such as Illustrator (Adobe Inc.) and Corel-DRAW (Corel Corp.) or packages that have been customised for the fashion industry such as Kaledo Style (Lectra), Vision fashion studio (Gerber), Tex-Design (Koppermann), etc. are also being used around the world. Specialised 2D CAD software, including packages such as cad.assyst (Assyst-Bullmer), Modaris (Lectra), Accumark (Gerber), Master Pattern Design (PAD System), TUKAcad (Tukatech), GRAFIS (Software Dr K. Friedrich), Audaces Apparel (Audaces), COAT (COAT- EDV-Systeme) and Fashion CAD(Cad Cam Solutions), support geometrical pattern drafting from first principles using only anthropometric measurements of the target size and shape.With the help of a 'digitiser' it is possible to input existing block patterns into virtually any of the various software packages that are currently available, and thus an extensive library of patterns in many sizes can be efficiently stored on the computer for future use [31].

Commercially available 3D CAD systems for 3D garment visualization and virtual try-on software can be categorized into two groups, based on the working procedure, to create 3D designs. First group allows designers to develop garment silhouettes and styles in a 3D environment according to their preference, e.g. Virtualfashion1 by Reyes Infografica and TPC Parametric Pattern Generator by TPC. Other types of 3D CAD system allow the importation of 2D pattern pieces from the appropriate 2D CAD software to wrap them onto a virtual model in order to visualize the virtual product and also to simulate fabric drape and fit. For example, VstitcherTM by Browzwear, Accumark V-stitcher by Gerber, Haute Couture 3D by PAD system, 3D Runway by OptiTex (Figure 15), Modaris 3D FIT by Lectra (Figure 16), eFit Simulator by Tukatech, Vidya by Assyst-Bullmer[31].

For 3D to 2D pattern unwrapping, there has been no 3D CAD system readily available until recently, which could be directly used in the clothing industry [31]. Still, for that to be useful, 3D prototyping should go more to masses. Among the available software packages, 3D Interactive software (TPC) and the flattening tool of 3D Runway (OptiTex) provide the capability to execute pattern unwrapping in a very limited context. The DesignConcept software (Lectra) is capable of executing 3D to 2D pattern unwrapping, but is currently being promoted for use in car seat design and for technical textiles applications [31].

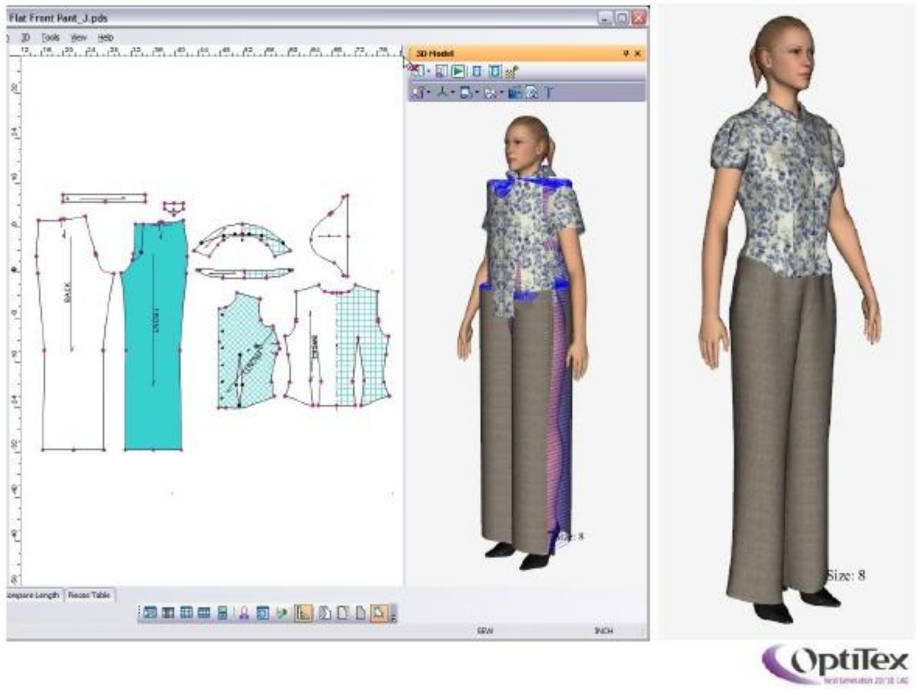


Figure 15. 3D Runway by OptiTex [32].

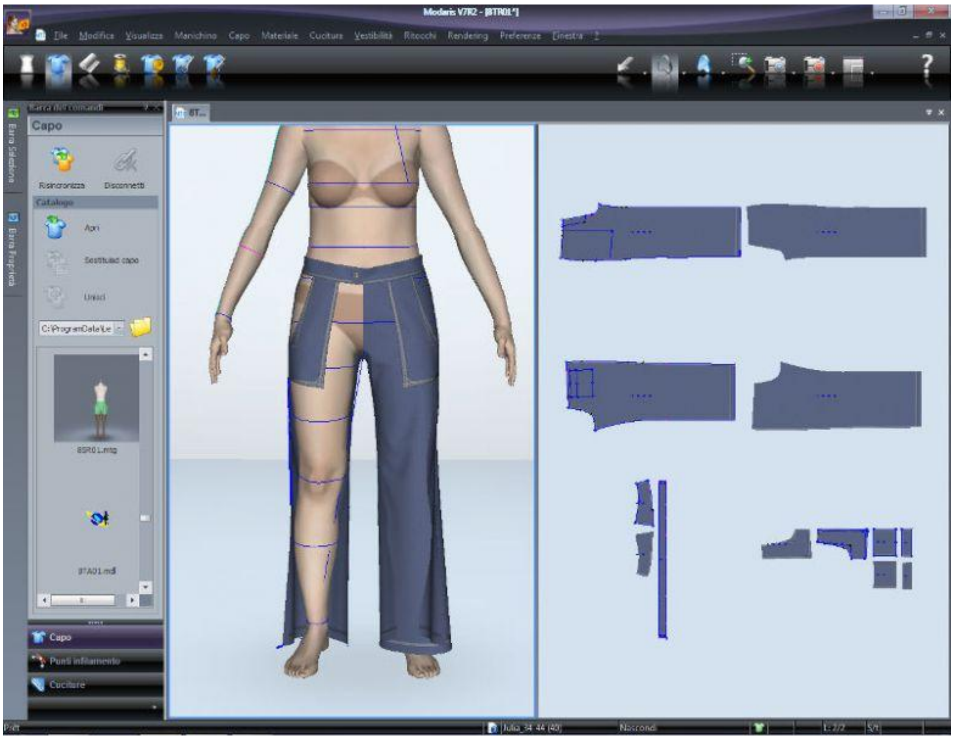


Figure 16. Modaris 3D fit by Lectra [33].

In this work, Modaris 3D Fit by Lectra is used. It is a 3D virtual prototyping solution, which associates 2D patterns, fabric information and 3D virtual models. It enables simulation of 3D design from 2D pattern pieces developed by a wide range of 2D CAD software and helps the designer to validate fabrics, motifs and colours. It allows an onsite or remote review of the virtual prototypes in three dimensions and provides the opportunity to check garment fit in various fabrics and sizes. It has a broad library of over 120 materials together with their mechanical characteristics. It also allows the designer to input new fabric properties in order to view differential drape [31]. Additionally, user can make their own model which helps to see the fit personally. Though that is not necessary for big brands, it helps to see and learn the 2D patterns.

In the 2007 article from Material Science about STAPRIM states that the existent 3D cannot provide a complex impact of all parameters – the multi-shaped surface descriptions of an individual human body and the description of the shape-creating characteristics of textiles [34]. That can already be disproved with Modaris 3D Fit because it lets to change model shape, stand and pose. Also, having several different materials and possibility to make your own material, helps to see the whole characteristics of the fit. This shows how rapidly the 3D technology for apparel industry develops.

Still, current 3D CAD systems are missing the most materials accuracy on human body. Motivated by the mathematic properties of developable surfaces, the flattening of free-form surfaces usually minimizes some measures of distortion characterized by the first fundamental form of surface. These measures are geometry-oriented such that fast and stable numerical process can be achieved. So, can the measures be material oriented? Given a piece of 3D cloth with the same geometry but different material, user should get different 2D patterns by flattening [35].

5. PRODUCTS' TECHNICAL DESCRIPTIONS

5.1 Jacket 1

Jacket 1 (Figure 17) is a men's everyday jacket two-part sleeves and roll collar. Jacket is made of soft shell material and velour material. Jacket is shaped with side body pattern and a center-back seam. At the back side seams are two slits. Bottom hem is finished with lining. Additionally, there are 3 ribbons (8 cm) for attaching a sling cord for carrying the jacket. Ribbons are at center back, front side seam on the right and back side seam on the left. Jacket's center-front is closed with a zipper. Center-front zipper ends at the center back, and are sewn between front and facing. Inner sides of slits have 2 magnetic snap buttons sewn by hand. Sleeve slits have 2 magnetic snap buttons. Locations are marked on pattern. Jacket has military-like shoulder pads that are attached to the product with velcro strips. Each product has two sets of shoulder pads: one with Lilypad parts and one without.

Jacket has 5 pockets: four pockets on the front and one inner chest pocket that is sewn between facing and side lining at chest height. Four outer layer pockets are on the front side. There are two horizontal flap pockets few centimeters from waistline. Also, two vertical zipper pockets that are next to the flap pockets.

Jacket has a zipper inside between right front lining and facing to access and remove electronic parts. Inside the jacket is a fabric piece with Lilypad and switch that is attached to the product from inside with velcro strips on shoulder line and sewable snap buttons at the chest. Jacket's electronic parts include Buzzer, Slide Switch, Light Sensor, LED-light and Lilypad Arduino Main Board. Everything is connected with conductive thread made from stainless steel fibers.

Velcro strips are sewed on the product's right shoulder, inside and outside. Additionally, non-conductive strips are sewn on left shoulder, only on the outside. The other side, in this case the hook (hard) side, of velcro is sewn on shoulder patches, where the Lilypad pieces are on, and on fabric piece where Lilypad itself is on. Lilypad fabric piece will between main material and lining. The fabric piece is attached to the velcro strips that are sewn inside the product on shoulder. Snap buttons are sewn on the chest piece and chest line on the product, inside and outside. See Figure 22, Figure 33, Figure 34 and Figure 35.

5.2 Jacket 2

Jacket 2 (Figure 18) is men’s everyday two-part sleeves and stand-up collar. Jacket is made of soft shell material and velour material.Jacket is shaped with side body pattern and a center-back seam. At the back side seams are two flaps. Bottom hem is finished with lining. Additionally, there are 3 ribbons (8 cm) for attaching a sling cord for carrying the jacket. Ribbons are at center back, front side seam on the right and back side seam on the left. Inner sides of slits have 2 magnetic snap buttons sewn by hand. Sleeve slits have 2 magnetic snap buttons. Locations are marked on pattern.Jacket has military-like shoulder pads that are attached to the product with velcro strips. Each product has two sets of shoulder pads: one with Lilypad parts and one without.

Jacket has 5 pockets: four pockets on the front and one inner chest pocket with zipper on the left side. Four outer layer pockets are on the front side. There are two horizontal flap pockets few centimeters from waistline. Also, two vertical zipper pockets that are next to the flap pockets.

Jacket’s center-front is closed with seven buttons and a zipper. Zipper is hidden under a center-front flap. Left zipper side is between flap facing and left facing. On the right side, the center-front zipper is between front part and right facing. Buttonholes are made through right center-front facing and front part of the jacket.

Jacket has a zipper inside between right front lining and facing to access and remove electronic parts. Inside the jacket is a fabric piece with Lilypad and switch that is attached to the product from inside with velcro strips on shoulder line and sewable snap buttons at the chest. Jacket’s electronic parts include Buzzer, Slide Switch, Light Sensor, LED-light and Lilypad Arduino Main Board. Everything is connected with conductive thread made from stainless steel fibers.

Velcro strips are sewed on the product’s right shoulder, inside and outside. Additionally, non-conductive strips are sewn on left shoulder, only on the outside. The other side, in this case the hook (hard) side, of velcro is sewn on shoulder patches, where the Lilypad pieces are on, and on fabric piece where Lilypad itself is on. Lilypad fabric piece will between main material and lining. The fabric piece is attached to the velcro strips that are sewn inside the product on shoulder. Snap buttons are sewn on the chest piece and chest line on the product, inside and outside. See Figure 22, Figure 33, Figure 34 and Figure 35.

5.3 Jacket 3

Jacket 3 (Figure 19) is a men's everyday jacket with asymmetrical center-front closing and standing collar. Jacket is made of soft shell material and velour material.Jacket has two-part sleeves. Jacket is shaped with side body pattern, and a center-back seam. Jacket's center-front is closed with three buttons and a zipper. Zipper is hidden under a center-front flap. Zipper with center-front facing starts from the neckline and ends with bottom hem facing.

On the left side, the center-front zipper is sewn between left facing and lining. On the right side, the center-front zipper is sewn between front part and right facing. Buttonholes are made through center-front facing, forepart and 2 pieces of extra fabric piece on the top of the forepart. Inner sides of slits have 2 magnetic snap buttons sewn by hand. Sleeve slits have 2 magnetic snap buttons. Locations are marked on pattern.Jacket has military-like shoulder pads that are attached to the product with velcro strips. Each product has two sets of shoulder pads: one with Lilypad parts and one without.

Jacket has an extra fabric piece over the chest area which is attached to the product from left side body and back seam, armhole seam, left shoulder front yoke seam, left front neckline and center-front closing until chest line. Bottom hem is finished with lining.

Jacket has 5 pockets: four pockets on the front and one inner chest pocket with zipper on the left side. Four outer layer pockets are on the front side. There are two horizontal flap pockets few centimeters from waistline. Also, two vertical zipper pockets that are next to the flap pockets. Jacket has a zipper inside between right front lining and facing to access and remove electronic parts.

Jacket has a zipper inside between right front lining and facing to access and remove electronic parts. Inside the jacket is a fabric piece with Lilypad and switch that is attached to the product from inside with velcro strips on shoulder line. Jacket's electronic parts include Buzzer, Slide Switch, Light Sensor, LED-light and Lilypad Arduino Main Board. Everything is connected with conductive thread made from stainless steel fibers.

Velcro strips are sewed on the product’s right shoulder, inside and outside. Additionally, non-conductive strips are sewn on left shoulder, only on the outside. The other side, in this case the hook (hard) side, of velcro is sewn on shoulder patches, where the Lilypad pieces are on, and on fabric piece where Lilypad itself is on. Lilypad fabric piece will between main material and lining. The fabric piece is attached to the velcro strips that are sewn inside the product on shoulder. See Figure 22, Figure 33, Figure 34 and Figure 35.

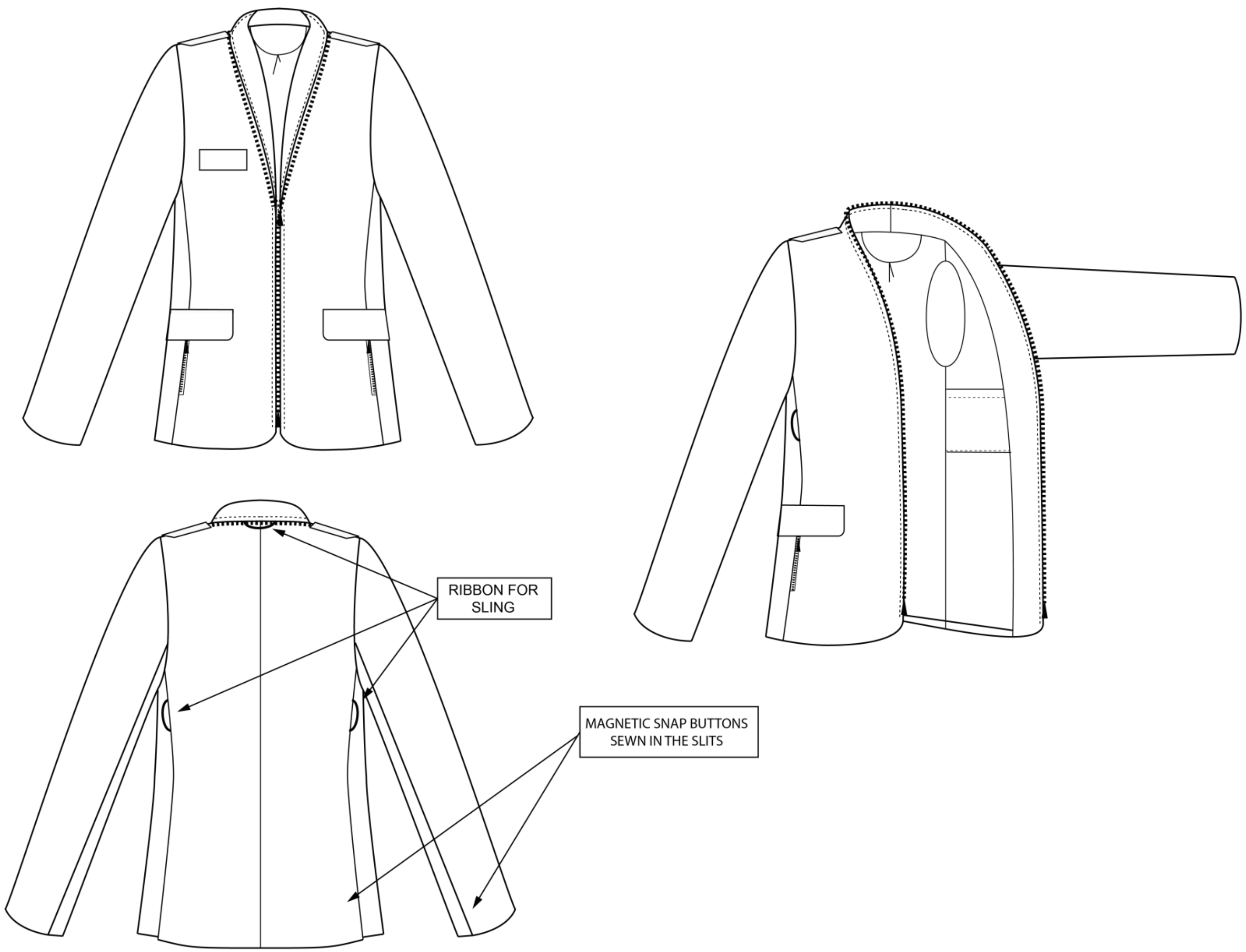


Figure 17. Jacket 1 technical drawing

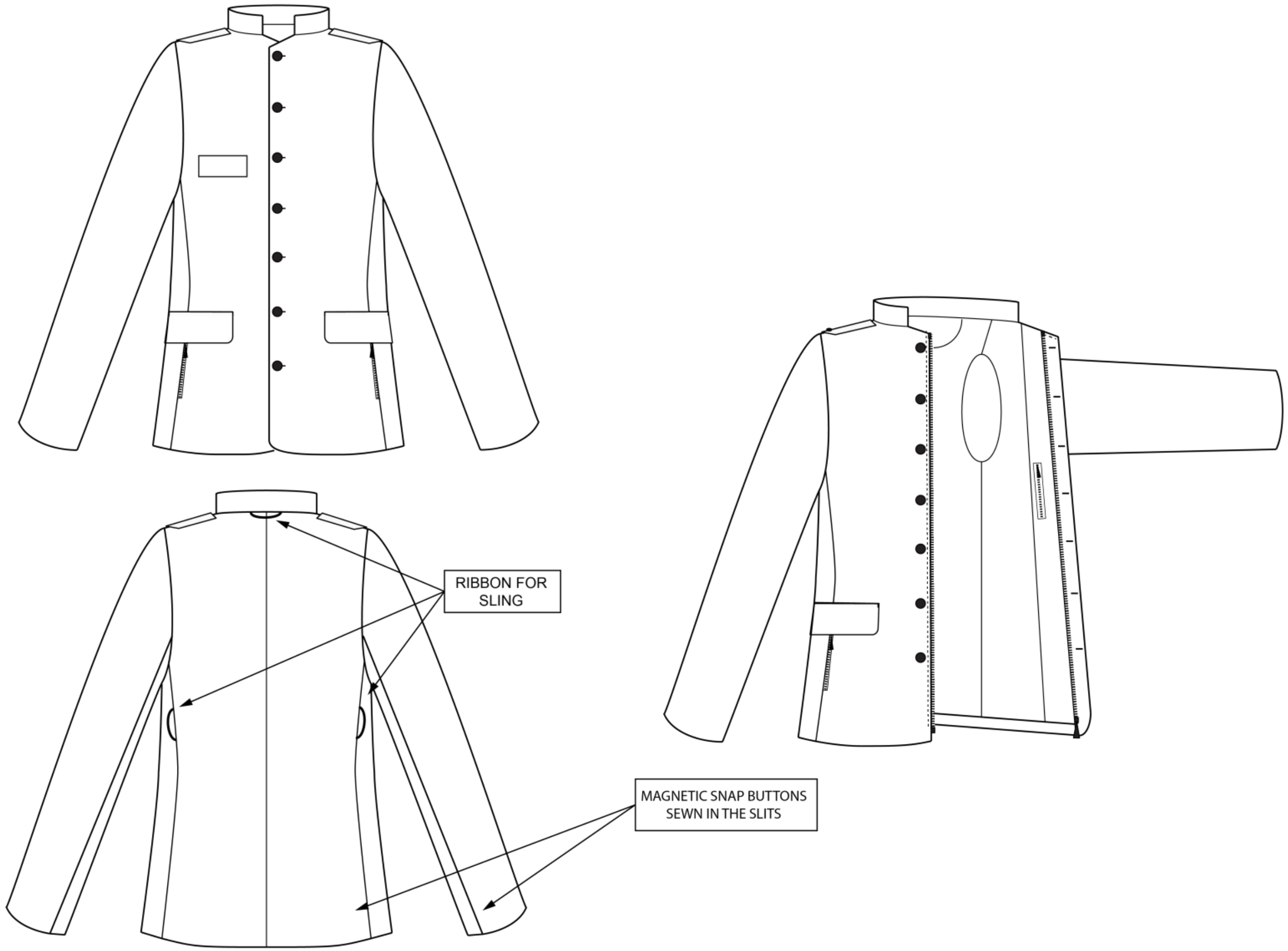


Figure 18. Jacket 2 technical drawing

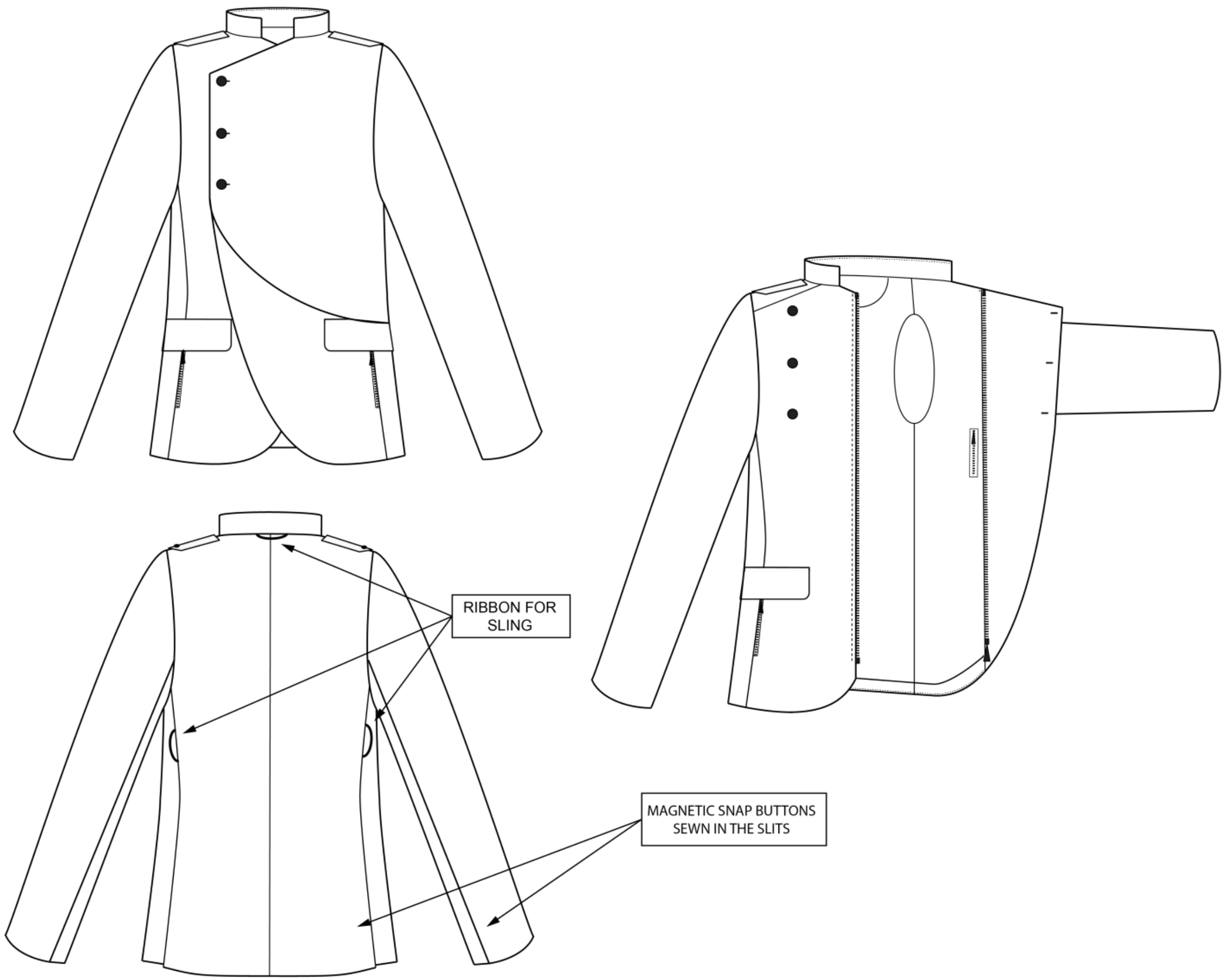


Figure 19. Jacket 3 technical drawing

6. ADOPTING LILYPAD TO THE PRODUCT

6.1 Lilypad output devices

Lilypad has several output options, e.g. LED lights, switches, temperature sensor, light sensor, accelerometer etc. After receiving the parts, defining everything was necessary (see Figure 19 and Table 5).

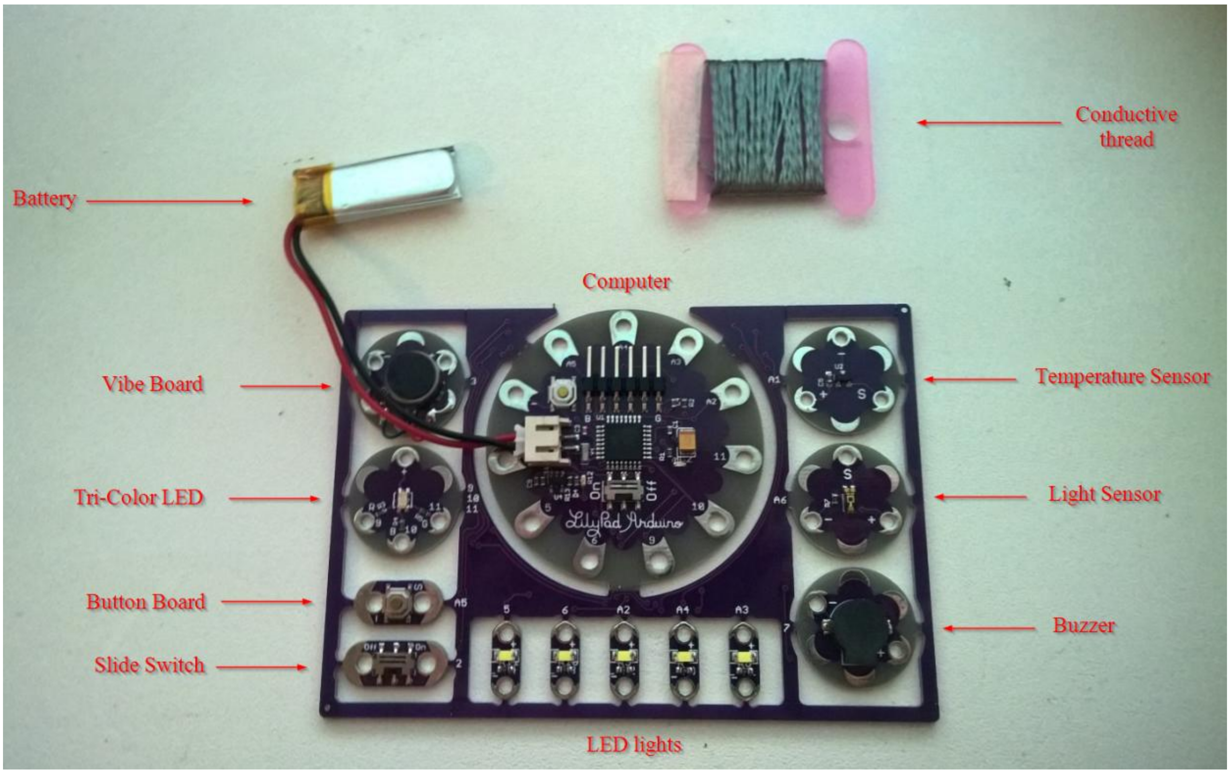


Figure 20. Lilypad Arduino when received

Table 5. Lilypad part list [20]explains every parts purpose and effect. Accelerometer was ordered separately. The battery was not connected to the board when received. Table is missing battery, conductive thread and FTDI basic breakout board with USB and six pins that makes programming the board possible. The FTDI chips implement the USB protocol stack. The responsibility of this hardware is to explain to PC what it is (using some identification information) such that the computer can load the right driver for it, and also to manage the data transactions with the PC there-on after. Once those drivers are loaded, this would specify a command set that your PC can use to query the chip.

Table 5. Lilypad part list [20].

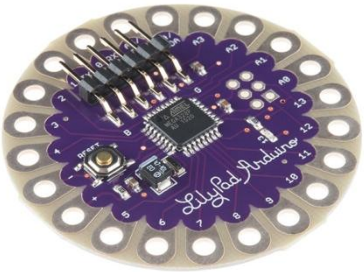
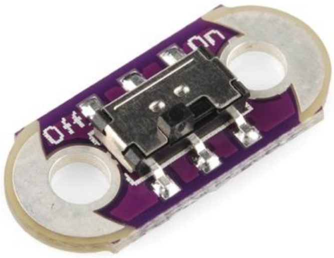
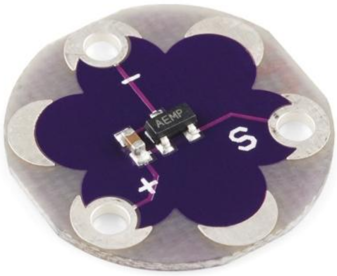
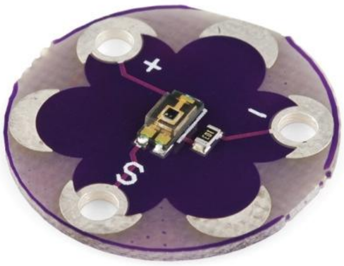
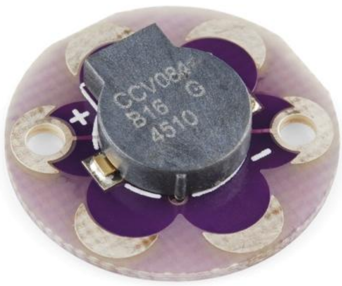
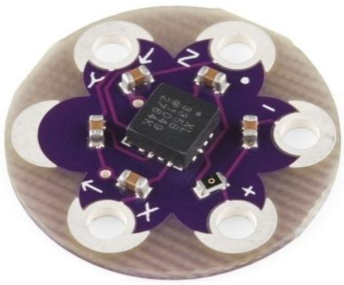
Part Name	**Picture**	**Effect**
Main Board or Computer		Main Board is an Arduino-programmed microcontroller with wide tabs that can be sewn down and connected with conductive thread. The LilyPad Arduino consists of an ATmega328 with the Arduino bootloader and a minimum number of external components. This board runs from 2V to 5V and offers large pin-out holes for easy sewing. Each of these pins, with the exception of (+) and (-), can control an attached input or output device (like a light, motor, or switch).
Vibe Board		It is a powerful vibration motor when 5V is applied. Uses a surface mount motor which is less likely to be damaged during use.
Tri-Color LED		Tri-Color LED board blinks red, green and blue colors by grounding one of the R/G/B pins to illuminate that channel.
Button Board		Button Board gives the user a discrete, non-sharp button interface. Can be used to make noise or any kind of action during pushed down.
Slide Switch		Can be used to control LEDs, buzzers etc. The switches on each board are rated for 4 volts at 300mA, but will work at 5 volts with a reduction in current.

Table 5. Lilypad part list [20].

Part Name	**Picture**	**Effect**
Temperature Sensor		A small thermistor type temperature sensor. This sensor will output 0.5V at 0 degrees C, 0.75V at 25 C, and 10mV per degree C. Doing an analog to digital conversion on the signal line will allow to establish the local ambient temperature.
Light Sensor		Reacts to light. Outputs an analog value from 0 to 5V. With exposure to daylight, this sensor will output 5V. Covering the sensor with your hand, the sensor will output 0V. In a normal indoor lighting situation, the sensor will output from 1 to 2V.
Buzzer		Creates different noises based on the different frequency of I/O toggling.
Accelerometer		Can detect joint movement as well as inclination and vibration.

6.2 Functions for the jacket

There are endless options how to use Lilypad or any other e-textile option. Light sensor could be used to light up a LED-light or make the vibe board vibrate. Accelerometer could be used to remind the user to get up and move. Temperature senor could help the user to understand that it is time to cool down and so on.

In this case, switch with buzzer is programmed to make noise after a certain time. For example, the buzzer is turned on with a switch and it will let the user know that 15 minutes has passed and it is time to go to a meeting. Additionally, light sensor with LED-light is programmed to make the user seen in the dark. That is done programming by light sensor sending the information to LED-light to light up in certain dark level.

To help program Lilypad, Arduion has set up free software The Arduino Integrated Development Environment (IDE) (Figure 21). That contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them [36].

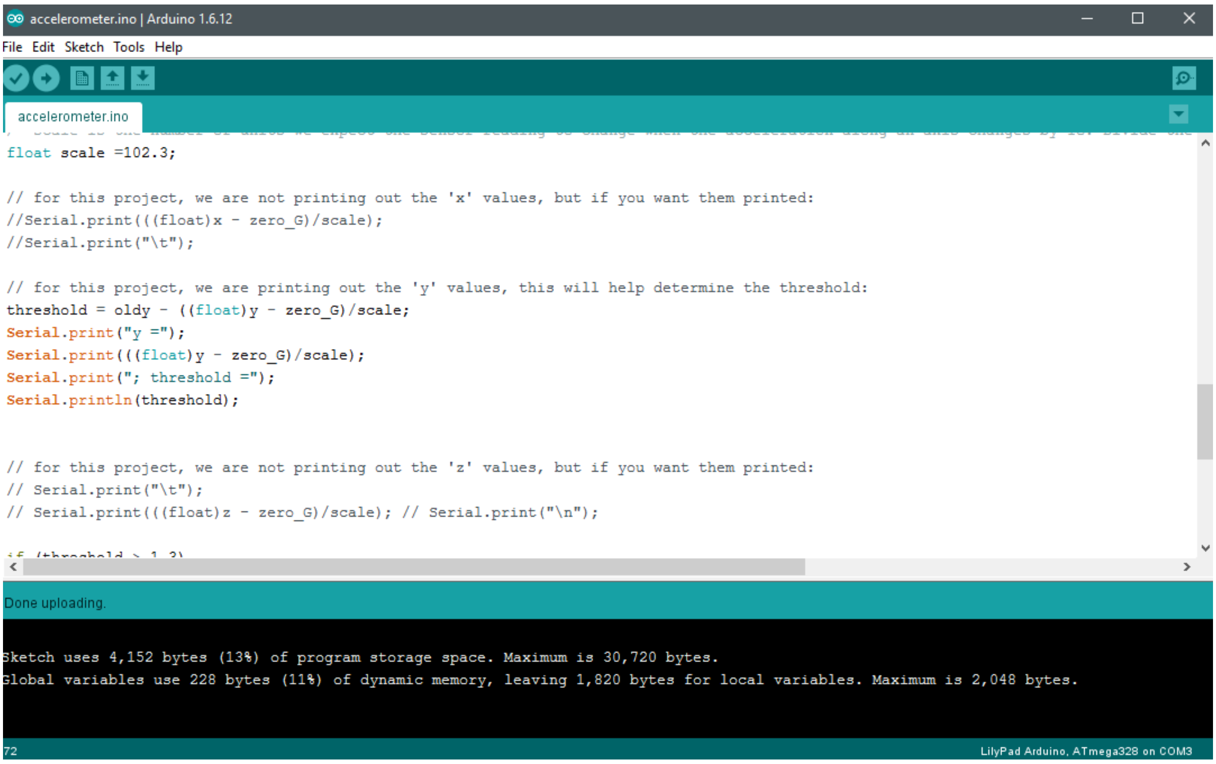


Figure 21. The Arduino Integrated Development Environment (IDE) while writing a code.

An example how to light up a LED-light helps to show how to hook up the Lilypad and how the code could look like. The main idea is that '+'-side of the LED-light goes to a certain leg from Lilypad main board, e.g. from number 6 leg, and '-'-side of the LED-light goes to '-' on the Lilypad main board. Then a program has to be written, so the main board would understand when the LED-light should be on or when it should blink, if that was the purpose for it. Therefore, the code was written and uploaded to the main board with USB cord and FTDI basic breakout board. The code tells the main board that it would delay the power to leg

6 after every 5000 milliseconds (5 seconds). Therefore, the light blinks for a second after every 5 seconds. The code [37] looks like this:

```
void setup()                  // the setup function runs once when you press reset or power the
board
{
pinMode(6, OUTPUT);        // initialize digital pin LED_BUILTIN as an output.
}

void loop()                 // the loop function runs over and over again forever
{
digitalWrite(6, HIGH);   // turn the LED on (HIGH is the voltage level)
delay(1000);                   // wait for a second
digitalWrite(6, LOW);    // turn the LED off by making the voltage LOW
delay(5000);                   // wait for a second
}
```

In this work the code looks like this [37], [38], [39]:

```
// constants won't change. Used here to set a pin number:

const int buzzerPin =  5;      // the number of the buzzer board pin
//const int maandusPin =  6;  // the ground (-) leg for buzzer


// Notes and their frequencies
const int C = 1046;
const int D = 1175;
const int E = 1319;
const int F = 1397;
const int G = 1568;
const int A = 1760;
const int B = 1976;
const int C1 = 2093;
const int D1 = 2349;

// Variables will change :
int aegheliseda = LOW;  //  used to set the buzzer

// Generally, you should use "unsigned long" for variables that hold time
// The value will quickly become too large for an int to store
unsigned long previousMillis = 0;        // will store last time buzzer was updated
int long interval = 100;           // interval at which to vibe (milliseconds)

// Lightsensor Muutujad

// The dark variable determines when we turn the LEDs on or off.
```

```
// Set higher or lower to adjust sensitivity.
const int darkLevel = 20;

// Create a variable to hold the readings from the light sensor.
int lightValue;

// Set which pin the Signal output from the light sensor is connected to
int sensorPin = A2;

// Set which pin the LED that lights up to light sensor is connected to.
int ledPin = 10;

void setup() {
// set the digital pin as output:
pinMode(buzzerPin, OUTPUT);
pinMode(6, OUTPUT);
digitalWrite(6, LOW);

// Valgussensor setup
 // Set sensorPin as an INPUT
pinMode(sensorPin, INPUT);

// Set LED as outputs
pinMode(ledPin, OUTPUT);

// Set pin A3 to use as a power pin for the light sensor
pinMode(A3, OUTPUT);
digitalWrite(A3, HIGH);

// Initialize Serial, set the baud rate to 9600 bps.
Serial.begin(9600);
}

void loop() {

// Lightsensor Loop
// Read the light sensor's value and store in 'lightValue'
  lightValue = analogRead(sensorPin);

// Compare "lightValue" to the "dark" variable
if (lightValue <= darkLevel) // If the reading is less then 'darkLevel'
   {
      digitalWrite(ledPin, HIGH); // Turn on LED
Serial.print("Valgussensor LED ON");
Serial.print("\t");
   }
else // Otherwise, if "lightValue" is greater than "dark"
   {
digitalWrite(ledPin, LOW);  // Turn off LED
   }
```

```
delay(10);
//Lightsensor Loop end

// check to see if it's time to buzz that is, if the
// difference between the current time and last time it buzzed
// the buzzerboard is bigger than the interval at which you want to buzz the buzzerboard.

unsigned long currentMillis = millis();
if (currentMillis - previousMillis >= interval){
     // save the last time the buzzer made noise
   previousMillis = currentMillis;

// if the buzzerboard is off turn it on and vice-versa:
if (aegheliseda == LOW) {
     interval = 1000;
     //vibeState = HIGH;
tone(buzzerPin, D1);
Serial.print("Heliseb");
Serial.print("\t");
     aegheliseda = HIGH;
   } else {
      interval = 10000;
     //vibeState = LOW;
noTone(buzzerPin);
Serial.print("Ootab  ");
Serial.print(interval);
Serial.print("ms");
Serial.print("\t");
     aegheliseda = LOW;
      }
  }

}
```

6.3 Placement of Lilypad in the product

It is important to let the user have a choice if they want to use electronic devices in the jacket or not. For example, during leisure time, buzzer may not be necessary. Also, cleaning the jacket can be difficult with electronic parts inside. Therefore, all the parts should be removable. That is done with velcro strips that conduct electricity and sewable snap buttons. Two different ways are used to see how they react and which option would be better. So, velcro strips are sewed on the product’s right shoulder, inside and outside. Additionally, non-conductive strips are sewn on left shoulder, only on the outside. The other side of velcro is sewn on shoulder patches where the Lilypad pieces are on and on fabric piece where Lilypad itself is on. Lilypad fabric piece will between main material and lining. The fabric piece is attached to the velcro strips that are sewn inside the product on shoulder. Snap buttons are sewn on the chest piece and chest line on the product, inside and outside. The idea is the same that was with the velcro strips.

Choosing the placement of the Lilypad in the product needed testing. The 'Buzzer' part was chosen to put on chest. Main reason for the decision was based on study by Nem Khan Dim and Xiangshi Ren from Kochi University of Technology in Japan. The study was to determine the best placement for wearable vibration devices which included laboratory tests and real-life feedback from users [41]. Light sensor with LED-light is put on shoulder to receive the right light amount and LED-light is seen. Lilypad schematic is seen on Figure 22.

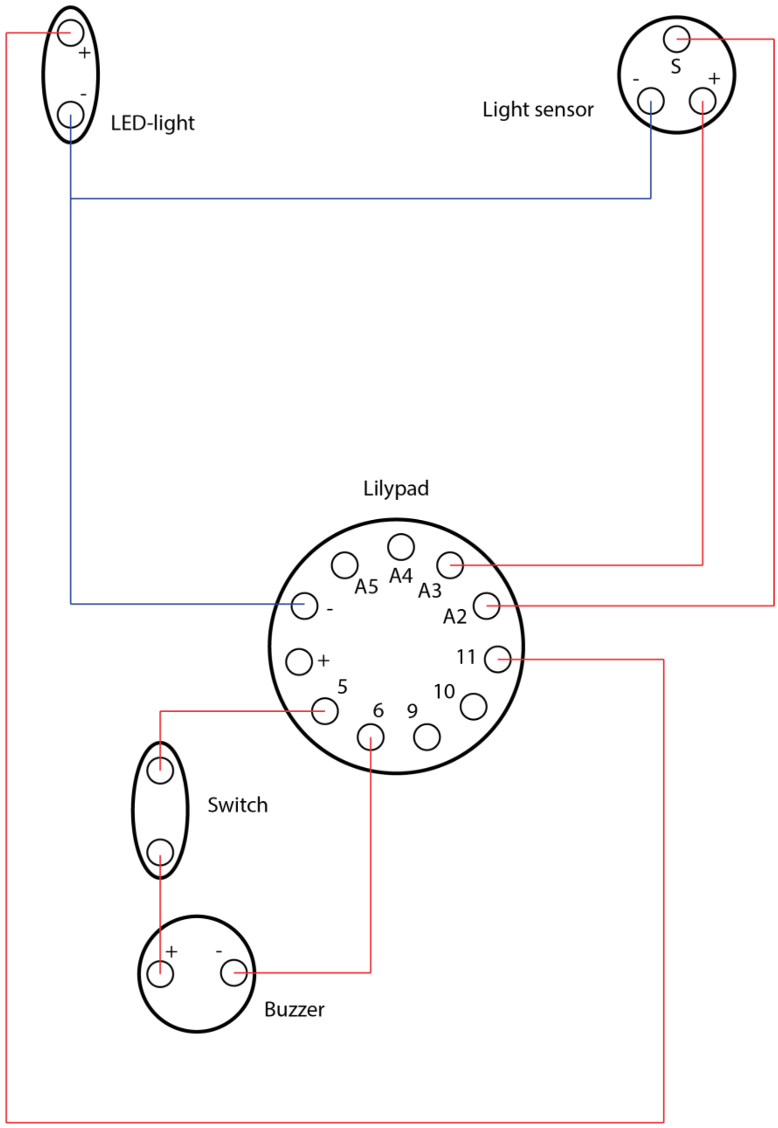


Figure 22. Lilypad schematics in the product.

7. PATTERN AND PROTOTYPE DEVELOPMENT

Pattern was first tried out by sketching it from the start with models measures. The second version was tried out by taking apart existing suit jacket, in this case Mosaic suit jacket. That helped to learn how it is done in the industry (Figure 23 and Figure 24). The end pattern was the hybrid of both patterns.

Figure 23. Inside of Mosaic jacket's front.

Figure 24. Inside of Mosaic jacket's sleeve

To make sure that the model would be with average industry measures, different apparel brand measurement tables were investigated (Table 6). By comparing them to the model's measurements (Table 7) it could be concluded that the measurements are fine because the differences are 0,5-1,0 cm. Only sleeve length difference is 3,0 cm but that is counted as a personal trait.

Table 6. Different brands basic measurements for men's jacket

Size guide for size S/48 (cm)				
Measurement	**Baltika Group, Baltman regular**	**Denim Dream**	**H&M**	**Gowri**
Chest	96	96	96	96
Waist	84	83	84	86
Hip	100	100	100	-
Back length	-	-	-	-
Sleeve length	65	62	-	63

Table 7. Measurements of a model

Measurement	**cm**	**1/2**	**1/3**	**1/4**	**1/5**	**1/6**
Height	185,5	92,8	61,8	46,4	37,1	30,9
Chest	95,5	47,8	31,8	23,9	19,1	15,9
Scye depth	26,5	13,3	8,8	6,6	5,3	4,4
Waistline	83,0	41,0	27,3	20,5	16,4	13,7
Back length	41,0	20,5	13,7	10,3	8,2	6,8
Back width	34,0	17,0	11,3	8,5	6,8	5,7
Scye width	36,0	18,0	12,0	9,0	7,2	6,0
Neck size	39,0	19,5	13,0	9,8	7,8	6,5
Sleeve length	68,0	34,5	23,0	17,3	13,8	11,5
Shoulder seam	15,0	7,5	5,0	3,8	3,0	2,5
Cuff size	28,0	14,0	9,3	7,0	5,6	4,7

7.1 Pattern development for Jacket 1

The pattern development was the basis of this part of the work. The aim was to make only one sample instead of several prototypes to find the perfect fit. Therefore, 3D visualization with Lectra software was used. This kind of pattern development would reduce textile waste tremendously because average prototype number per model in fashion industry is two. The pattern was put on the mannequin basically after every change. Figure 25 shows the fit of the jacket after digitalizing. Figure 26shows the pattern after making changes based on the 3D mannequin fittings.

Figure 25. Jacket after digitalizing the pattern, without any changes.

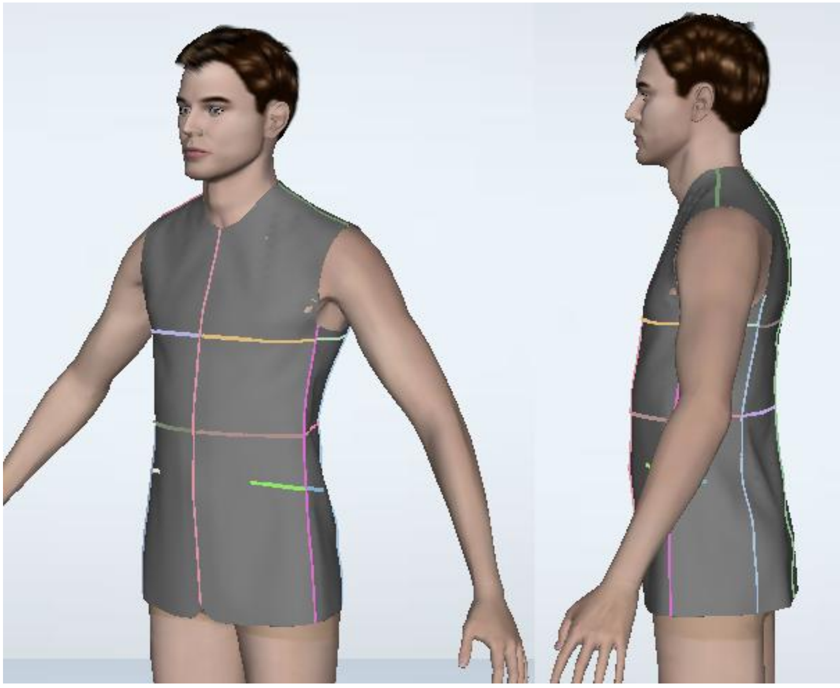


Figure 26. Jacket after making pattern changes.

By attaching the sleeves, the jacket did not fit the mannequin. Figure 27shows the fit. Colors on the jacket show the ease of the jacket. White means there is 0 ease, blue parts up to 10 cm of ease and yellow color indicated that the jacket is tight. It should suggest that the back width is too small. Also, the top sleeve width from that part is too small. Furthermore, the shoulder line could be wrong. In the end, at forepart shoulder line was brought down 1,5 cm and length was shortened by 1 cm, back and top sleeve width was made bigger. The results of changes are seen in Figure 28.

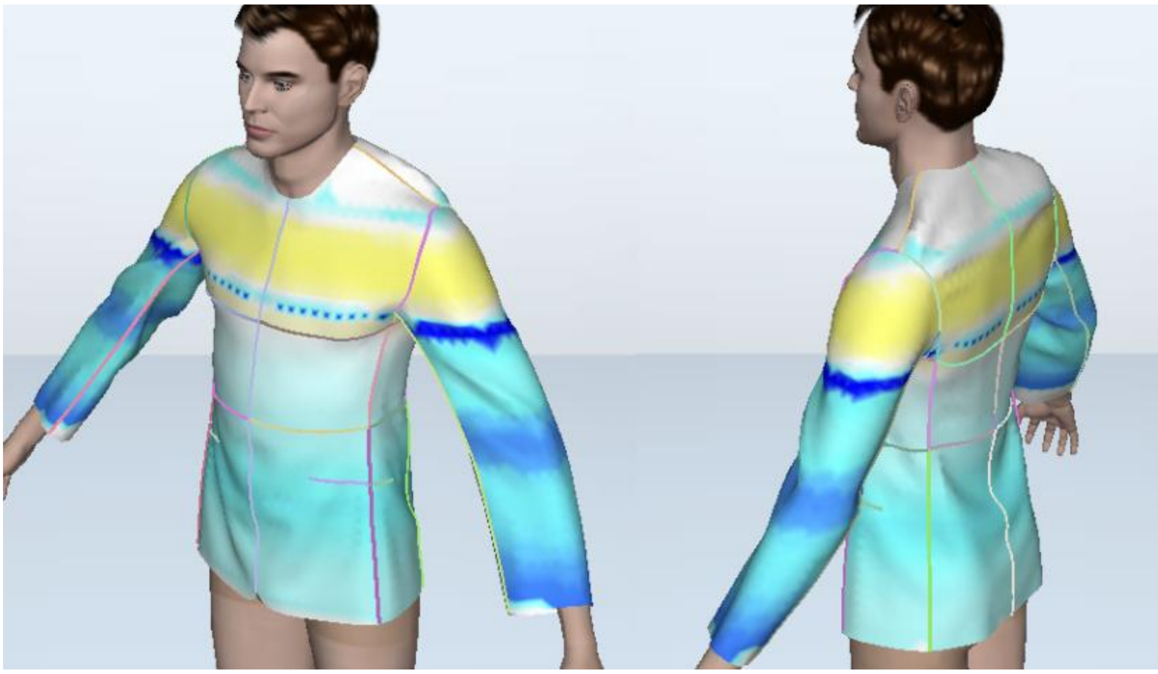


Figure 27. Fit after attaching the sleeves.

The colorful lines show the seams which help to see, for example, if the shoulder seam is in the correct place. Additionally, if there is an error with assembling the jacket in 3D it is easier to find the mistake. Figure 29 shows all the details that the jacket consists of with the help of different colors. The patterns are seen in Appendix 5.

Figure 28. Jacket fit after making the last changes.

Figure 29. Jacket details are highlighted to distinguish them better.

7.2 Pattern development for Jacket 2 and Jacket 3

When the pattern was set for Jacket 1, the other two patterns could be done. The changes were done only in the front. The pattern could again be checked in 3D environment. To show different options, the model is put to different postures. The results are seen in Figure 30 and Figure 31. The patterns are seen in Appendix 5.

Figure 30. Jacket 2 in 3D environment.

Figure 31. Jacket 3 in 3D environment.

7.3 Prototype development

The main prototype development took place in Modaris 3D environment. Therefore, when the prototype itself was sewn ready, it was just put on the model to see the end result (Figure 32).Additional pictures of the prototype are seen in Appendix 9 (Figure 54, Figure 55, Figure 56, Figure 57, Figure 58).

Figure 32. First prototype worn by the model

Light sensor with LED-light is on right shoulder pad that is put on the product with conductive velcro (Figure 33). Buzzer is on right chest piece that is put on the product with sewable snap buttons (Figure 34). The removable Lilypad piece is between lining and main material at front on the right side. It is removable with velcro at the shoulder and snap buttons at the chest (Figure 35).

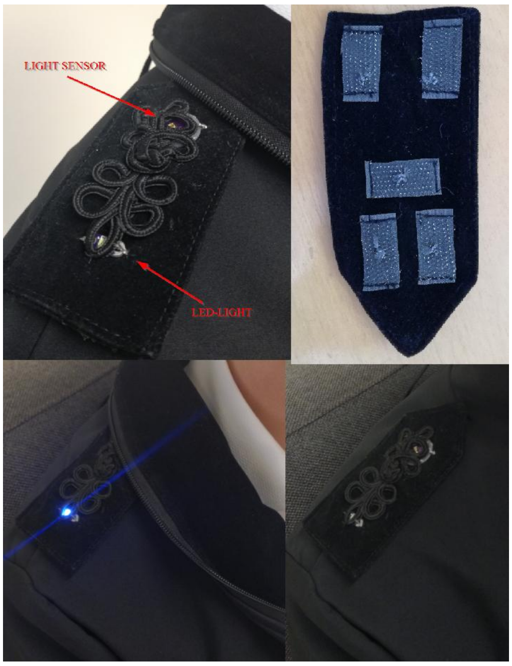


Figure 33. Light sensor with LED-light on right shoulder pad.

Figure 34. Buzzer on right chest piece.

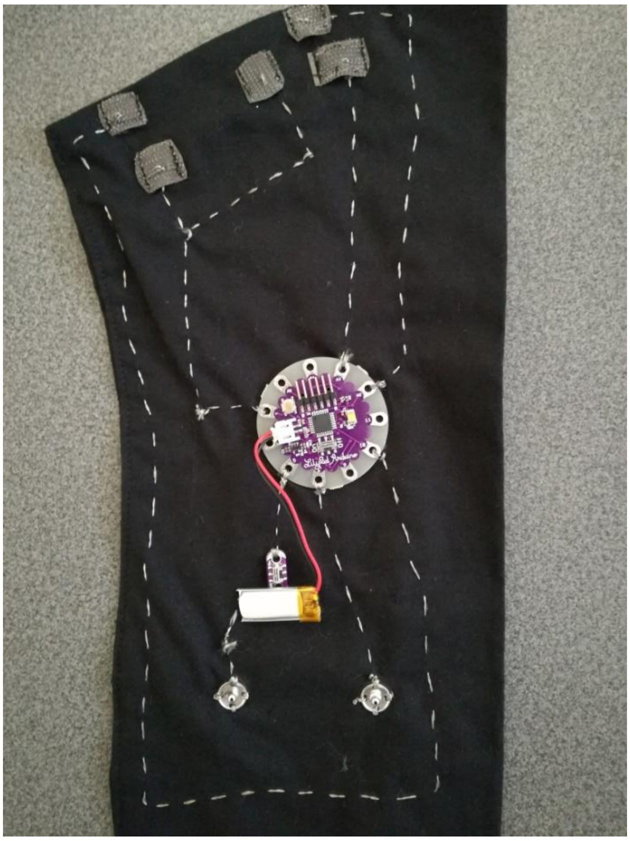


Figure 35. The removable Lilypad piece.

The information about sewing the prototype is seen in product cards in Appendix 6. Product card gives a good overview of the product to production. It shows the main sewing instructions and lengths of trims, e.g. zippers. Bill of materials is seen in Appendix 7 which also includes the net cost of each product. Sewing technology is seen in Appendix 8. It explains the sequence of sewing operations made during prototype making. Based on the experience in clothing manufacturing, the supposed sewing time would be 120 minutes with the price of 0,5 €/minute. Cutting is additional 10% of the time, in this case then 12 minutes. Therefore, the processing time is 132 minutes. The usual profit percentage is 50-75%. In this case, 60% was chosen. So, the selling prices would be:

$$Selling\ price\ of\ Jacket\ 1 = (108 \times 160\%) + (132 \times 0{,}5) = 238{,}8€ \quad (2)$$

$$Selling\ price\ of\ Jacket\ 2\ and\ 3 = (114 \times 160\%) + (132 \times 0{,}5) = 248{,}4€ \quad (3)$$

The minute price could vary based on production and the quantity produce at one time. The minute price is offered based on inquires to different e-textile prototype makers. The current prototype electronics part was sewn in manually which needs time and craftsmanship.

Additionally, programming the Lilypad is not included, though if the program is set, it doesn't need more than just uploading.

Furthermore, because only one prototype was sewn, the sewing time is presumed. It could grow a lot and decrease by time. If the results are compared with the prices of possible competitors, e.g. Timberland, it is seen that the jackets in this work could be cheaper. Therefore, the possible manufacturing and selling of the jacket is possible because of affordable parts and sewing time. If the jacket would be resold in wholesale, the price could increase. Still, a lot of aspects are presumed because all production costs cannot be seen with one prototype.

7.4 Quality requirements for product

Quality requirements are essential part of the product and selling of one. Because the product consists of not only fabric and trims but also electronic devices, the quality requirements could also be considered as basic safety requirements. The specification consists of three parts: sewing the jackets, processing after sewing and processing electronic parts.

7.4.1 Sewing

1. Sewing main features:
    a. thread number 100 tex
    b. needle number 80
    c. 4 stitches per centimeter
    d. back stitch can be maximum 0,5 centimeters long
    e. seam allowance is 1,0 cm, allowed mistake 0,2 cm.
2. Needles have to be changed daily on the sewing machine.
3. Invisible zippers have to be sewn with special zipper foot.
4. Main fabric cannot be shrunken while sewing the zipper
5. Sleeve arcs have to be shrunken evenly and identically to each other.
6. Main material I and II cannot be shrunken unevenly to each other.

7.4.2 Sewing the electronic parts

1. Sewing machine has to be set up according to leg width.
2. Sewing machines used for sewing the electronic parts cannot be used for regular sewing.
3. Sewing machines used for sewing the electronic parts have to be cleaned end of every work day.
4. Conductive seam endings have to be made manually for making sure the loose ends would not create a short circuit.
5. Conductive seams have to be made according to the scheme drawn ahead.
   a. Conductive seam cannot interlock with another conductive seam, except when both seams are connect to ‘minus’-leg.
6. Conductive seams are put in the product after steaming and other quality control processes (thread cutting, seam checking etc).

7.4.3 Quality checking:

1. There cannot be any over stretching or shrinking within seams.
2. There cannot be any folds after steaming and ironing.
3. There cannot be any loose thread endings.
4. There cannot be any stains.
5. Seams have to be even.
6. Seams cannot be continued in the middle.

7.4.4 Steaming and ironing

1. Seams cannot be shining through after steaming and ironing.
2. There cannot be any folds after steaming and ironing.
3. Product has to be put on the hanger when leaving the steaming and ironing process.

7.4.5 Marking and packing

1. Product has to be on the hanger.
2. Hand tag is put on the neck facing with a pin.

3. Hand tag has to have a sticker with product’s information.
4. Product is covered with a plastic bag (size 50x90 cm) and closed from the bottom with two tape strips.
5. Second sticker with product’s information is put on the plastic bag’s upper right corner.
6. Packed product is put to cardboard box (size 590x350x590mm); 7 products per box.
7. On the top of the last product in the box goes extra cardboard for protection. Box is closed with wide tape.

CONCLUSION

Clothing industry is currently one of the biggest waste producers in the world. Living in the era when recycling and ecological lifestyle is not only necessary but also trending, researching durable materials, a great fit and extra value for clothes is crucial. Smart textile products create a new era of textile product development and design, manufacturing, sustainability and lifetime expectancy. Electronic textiles (e-textiles) feature an integration of textiles with electronics and other high-tech materials. The ongoing innovation process of e-textiles holds opportunities to prevent future end-of-life impacts.

There are already several options to create an e-textile product, e.g. conductive thread, conductive polymers, conductive inks, small sensors etc. Still, the main obstacle is that they are bulky and the batteries could still be too big or too weak to power the integrated circuit. On the other hand, the sensors and microcontrollers, like Lilypad Arduino, are relatively cheap and easily obtainable with instructions. Putting them to work is somewhat easy because of several openly shared instructions and videos. The whole idea of Lilypad was to make e-textile more popular, so sharing everything made with it is encouraged. Therefore, it could be concluded that there are already options to consider on the market.

The work consisted of two major parts: theoretical and experimental part. Theoretical part or research included smart textile options and other 3D CAD systems that are available on the market. Additionally, the safety of e-textile options wereinvestigated and calculated. The experimental part included conducting thorough product development process. That led to products' specifications and technical drawings. After specifications it was possible to make the patterns for the products. These were made with the help of Modaris 3D Fit program. In the end, first prototype was made.

In conclusion, the work was successful with making of first working prototype. Overall, the work gave an overview of smart textile system product development options and implementation. The main goal of this work was to see how obtainable the smart textile options are and how easily they could be integrated to a garment. The work met its goal by making a prototype which showed simple integration of electronics and textiles. The thesis could be further developed by researching faster production options, e.g. using printed circuit boards for integration, to the products and making the final sample.

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ABSTRACT

Clothing industry is currently one of the biggest waste producers in the world. Living in the era when recycling and ecological lifestyle is not only necessary but also trending, researching durable materials, a great fit and extra value for clothes is crucial. Smart textile products create a new era of textile product development and design, manufacturing, sustainability and lifetime expectancy. Electronic textiles (e-textiles) feature an integration of textiles with electronics and other high-tech materials. The ongoing innovation process of e-textiles holds opportunities to prevent future end-of-life impacts.

There are already several options to create an e-textile product, e.g. conductive thread, conductive polymers, conductive inks, small sensors etc. Still, the main obstacle is their bulkiness and the power source could still be too big or too weak to power the integrated circuit. On the other hand, the sensors and microcontrollers, like Lilypad Arduino, are relatively cheap and easily obtainable with instructions. Putting them to work is somewhat easy because of several openly shared instructions and videos. Therefore, it could be concluded that there are already options to consider on the market.

The work consists of two major parts: theoretical and experimental part. Theoretical part included research into smart textile options and available 3D CAD systems on the market. Additionally, the safety of e-textile options were investigated and calculated. The experimental part included conducting thorough product development process. That led to products’ specifications and technical drawings. After specifications it was possible to make the patterns for the products. These were made with the help of Modaris 3D Fit program. In the end, first prototype was made.

In conclusion, the work gave an overview of smart textile system product development options and implementation. The main goal of this work was to see how obtainable the smart textile options are and how easily they could be integrated to a garment. The work met its goal by making a prototype which showed simple integration of electronics and textiles. The thesis could be further developed by researching faster production options, e.g. using printed circuit boards for integration, to the products and making the final sample.

This thesis is written in English and is 67 pages long, including 7 chapters, 58 figures and 16 tables.

KOKKUVÕTE

Rõivatööstus on hetkel üks suurimatest jäätmete tekitajatest. Elades ajal, kus jäätmete ümbertöötlemine ja taaskasutamine on populaarne ja ka vajalik, on oluline otsida järjepidevalt vastupidavaid materjale ja uusi lahendusi, et rõivastele lisaväärtust luua. Intelligentsed tekstiilitooted on loomas rõivatööstuses uue ajastu, tuues kaasa uuendatud tootearenduse protsessi, disaini, tootmise ja toote eluea. Innovaatilise elektroonika ja rõivaste integratsioon, ehk e-tekstiil, võimaldab pikendada toote eluiga ja seeläbi ennetada jäätmete tekkimist.

Intelligentsete tekstiilitoodete loomiseks elektroonika abiga on mitmeid viise, kasutades näiteks elektritjuhtivat niiti, värve, polümeere või ka väikseid sensoreid. Siiski, põhiline takistus on nende jäikus, kui samalajal tekstiil on pehme ja paindlik. Samuti on energiaallikad, nagu patareid, veel üsnagi suured või nõrgad, et integreeritud vooluvõrgule piisav võimsus tagada. Samas on turul kergesti kättesaadavad mikrokontrollerid, nagu Lilypad Arduino, mis on küllaltki odavad, paljude juhenditega ja samas vajades üsna nõrka energiaallikat. Seetõttu saab väita, et laialdases kasutuses on juba olemas mitmeid variante, et e-tekstiile luua.

Töö koosnes kahest osast: teoreetiline ja eksperimentaalne. Teoreetilises osas uuriti, mis on hetkel turul kättesaadavad e-tekstiili võimalused ja 3D CAD süsteemid. Lisaks uuriti e-tekstiilide turvalisust ja kalkuleeriti ka prototüübi turvalisus. Eksperimentaalses osas teostati põhjalik tootearendus QFD meetodil. Selle põhjal koostati toodetele spetsifikatsioonid ja tehnilised joonised. Pärast spetsifikatsioone oli võimalik teha Modaris 3D Fit programmi toel toodetele lõiked. Lõpuks pandi paika elektroonika valik tootes Lilypad Arduino näitel ja tehti esimene prototüüp.

Töö andis ülevaate intelligentse tekstiilitoote arendamisest ja e-tekstiili võimaluste rakendamisest. Peamine ülesanne oli teha kindlaks võimalused e-tekstiili võimalused ja nende integreerimine rõivastesse. Töö tulemus oli esimene töötav prototüüp, mis näitab lihtsat elektroonika ja tekstiili integratsiooni. Tööd saaks edasi arendada uurides kiiremaid tootmise võimalusi, näiteks kasutades juba spetsiaalselt elektritjuhtivate kiududega prinditud tekstiili viimase prototüübi loomiseks.

See magistritöö on kirjutatud inglise keeles ja on 67 lehekülge pikk, sisaldades 7 peatükki, 58 joonist ja 16 tabelit.

APPENDIX 1. Questionnaire in English.

Perfect everyday jacket for men

What kind of jacket is really the best kind for men

* Mandatory

◯ Choose one option ☐ Choose many option, if necessary

1. **How old are you ? ***

....

2. **Do You have to be very active/move a lot throughout the day because of work/school ? ***

◯ Yes
◯ No
◯ Quite a lot but it depends on the day
◯ Other:

3. **Do You wear a jacket daily ? ***

◯ Yes, everytime I leave home
◯ No, I check the weather and then decide
◯ I do not own a jacket
◯ Other:

4. **Do You use a car to get around daily? ***

◯ Yes
◯ No
◯ Depends on the day
◯ Other:

5. **Please choose the most likable jacket type below ***

☐ Option 1
☐ Option 2
☐ Option 3
☐ Option 4
☐ Option 5
☐ Other:

1

2

3

4

5

6. **How important is the brand/producer of the jacket?** *

- Very important, I only buy certain brand products; e.g Hugo Boss, Adidas, Armani etc.
- Not that important but I check the brand/producer before buying
- Not important at all

7. **What brand's/producer's jacket are You using now?** *

- H&M
- Cropp/Reserved/Jack&Jones
- River Island
- Zara/Bershka/Pull&Bear
- Armani
- Hugo Boss
- Timberland
- Tommy Hilfiger
- Nike
- Adidas
- Puma
- Other:

8. **What do You not like about Your current jacket?** *

- [ ] Zipper/buttons/snapbuttons do not close/open easily/comfortably
- [ ] There is no hood
- [ ] There is a hood
- [ ] It's too short
- [ ] It has too short sleeves
- [ ] It's not breathable
- [ ] It's not water-resisant
- [ ] It's too tight
- [ ] It's too wide and big
- [ ] Other:

9. **What demands do You have about Your jacket's material?** *

- [ ] It would not wrinkle
- [ ] It would be breathable
- [ ] It would be wind-resistant
- [ ] It would be water-resistant
- [ ] It would keep warm
- [ ] Other:

10. **What kind of details should Your jacket have?** *

- [ ] patch pocket
- [ ] besom pocket
- [ ] flap pocket
- [ ] pocket with zipper
- [ ] inner pocket
- [ ] lapel/rever collar
- [ ] standing collar
- [ ] Other:

patch pocket

besom pocket

flap pocket

pocket with zipper

inner pocket

lapel/rever collar

standing collar

11. **What kind of front closing do You prefer the jacket to have?** *

- zipper
- zipper and button
- zipper and snapbutton
- button
- snapbutton
- I do not want the jacket to have front closing
- Other:

zipper

zipper and button

zipper and snapbutton

button

snapbutton

12. **How important is the price of the jacket** *

- It's very important, I base my decision solely on that
- Important but I do not base my decision only on that
- Not important, I check the overall look and comfort of the jacket before the price
- Other:

13. **What is the highest price that You are willing to pay for a jacket?** *

- 50 euros
- 75 euros
- 100 euros
- 150 euros
- 200 euros
- Other:

14. **Are there any specific technology or fabric used on the current jacket You own? And Is that important to You?** *

E.g the fabric is processed to be waterproof, Gore-Tex materials are used, smart textiles are used etc

15. **Do You wish to wear only a shirt under the jacket when You go outside?** *

E.g You want to wear only a shirt or also sweater, sweatshirt, suit jacket etc under the jacket

- I would prefer to wear only one layer under my jacket, e.g only shirt or sweater
- I prefer to wear multible layers under the jacket, e.g shirt and cardigan/sweater
- Not important

16. **Please describe Your perfect jacket**

APPENDIX 2. Questionnaire in Estonian.

Ideaalne meeste jakk

Milline on tegelikult meeste ideaalne igapäeva jakk

* Kohustuslik

1. **Kui vana Te olete** *

   ____

2. **Kas Te peate seoses kooli või tööga päeva jooksul palju ringi liikuma?** *
   Märkige ainult üks ovaal.
   - ◯ Jah
   - ◯ Ei
   - ◯ Üsna palju, kuid oleneb päevast
   - ◯ Muu: ______________________

3. **Kas kannate jakki igapäevaselt?** *
   Märkige ainult üks ovaal.
   - ◯ Jah, iga kord, kui kodust välja lähen
   - ◯ Ei, vaatan enne ilma ja kui külm väljas on
   - ◯ Ei oma jakki
   - ◯ Muu: ______________________

4. **Kas kasutate igapäevaseks ringi liikumiseks autot?** *
   Märkige ainult üks ovaal.
   - ◯ Jah
   - ◯ Ei
   - ◯ Üldiselt, kuid oleneb päevast
   - ◯ Muu: ______________________

5. **Palun valige enim meeldiv jaki mudel** *
   Märkige kõik sobivad.
   - ☐ Valik 1
   - ☐ Valik 2
   - ☐ Valik 3
   - ☐ Valik 4
   - ☐ Valik 5
   - ☐ Muu: ______________________

Ideaalne meeste jakk

1

2

3

4

5

6. **Kui oluline on uue jaki valimisel jaki brändi/tootja?** *

Märkige ainult üks ovaal.

- Väga oluline, ostan ainult teatud brändi/tootja tooteid (näiteks ainult Armani tooteid)
- Ei ole väga oluline, kuid jälgin, mis brändi/tootja toode on
- Ei ole üldse oluline
- Muu: ____________

7. **Mis brändi/tootja jakki hetkel kasutate?** *

Märkige ainult üks ovaal.

- H&M
- Cropp/Reserved/Jack&Jones
- River Island
- Zara/Bershka/Pull&Bear
- Armani
- Hugo Boss
- Timberland
- Tommy Hilfiger
- Nike
- Adidas
- Puma
- Muu: ____________

8. **Mis Teile praeguse jaki/üleröiva juures ei meeldi?** *

Üleröivas, nagu näiteks mantel, jope ja muu toode, mida välja minnes selga panete

Märkige kõik sobivad.

- [ ] Lukk/Nööbid/Trukid ei käi mugavalt lahti/kinni
- [ ] Kapuutsi pole
- [ ] Kapuuts on
- [ ] Liiga lühike
- [ ] Liiga lühikesed varrukad
- [ ] Jakk ei lase õhku läbi
- [ ] Jakk ei ole veekindel
- [ ] Jakk on liiga kitsas
- [ ] Jakk on liiga lai ja lohvakas
- [ ] Muu: ____________

9. **Millised nõudmised oleksid Teil jaki/pintsaku materjalile?** *
Märkige kõik sobivad.

- [ ] ei kortsuks
- [ ] laseks õhku läbi
- [ ] oleks tuultpidav
- [ ] oleks vetthülgav (keha jääks näiteks vihmaga kuivaks)
- [ ] hoiaks sooja
- [ ] Muu: ______

10. **Millised detailid võiksid tootel kindlasti olla?** *
Märkige kõik sobivad.

- [ ] pealeõmmeldud taskud
- [ ] nööpauktasku
- [ ] klapiga tasku
- [ ] lukuga tasku
- [ ] põuetasku
- [ ] reväärkrae
- [ ] püstkrae
- [ ] Muu: ______

pealeõmmeldud tasku

nööpauktasku

klapiga tasku

lukuga tasku

põuetasku

reväärkrae

püstkrae

11. **Milline kinnis võiks jakil ees olla (kuidas jakki eest kinni panna)?** *
Märkige ainult üks ovaal.

- Lukuga
- Luku ja nööpidega
- Luku ja trukkidega
- Nööpidega
- Trukkidega
- Ei soovi, et jakk eest kinni käiks
- Muu: ______________________

Lukuga

Luku ja nööpidega

Luku ja trukkidega

Nööpidega

Trukkidega

12. **Kui tähtis on jaki hind?** *
Märkige ainult üks ovaal.

- ◯ Väga tähtis, teen otsuse ainult hinna põhjal
- ◯ Tähtis, aga ei tee otsust ainult selle põhjal
- ◯ Ei ole tähtis, vaatan enne muid omadusi, nagu mugavus, välimus jne
- ◯ Muu: ....

13. **Mis on kõrgeim hind, mida olete nõus maksama jaki eest?** *
Märkige ainult üks ovaal.

- ◯ 50 eurot
- ◯ 75 eurot
- ◯ 100 eurot
- ◯ 150 eurot
- ◯ 200 eurot
- ◯ Muu: ....

14. **Kas praeguse jaki puhul, mida kannate, on kasutatud erilist tehnoloogiat või kangast? Kas see on oluline?** *
Näiteks kangas on töödeldud veekindlaks, on kasutatud Gore-Tex materjale, on kasutatud tarke tekstiile ja tehnoloogiat jne.

15. **Kas välja minnes soovite ülerõiva alla ainult särki?** *
Näiteks kas jakki kandes, kannate selle all ainult särki, või ka pintsakut/pusa/kampsunit jne
Märkige ainult üks ovaal.

- ◯ Ma eelistaks välja minnes ainult ühte kihti ülerõivast, näiteks ainult pintsakut/kardigani või ainult mantlit/jopet
- ◯ Ma eelistan kanda mitut ülerõiva kihti, et kindlasti palav ega külm ei hakkaks, näiteks välja minnes panna selga lisaks ka jope/mantel
- ◯ Ei ole oluline

16. **Palun kirjelda, milline on Teie ideaalne jakk!**

APPENDIX 3. Questionnaire results.

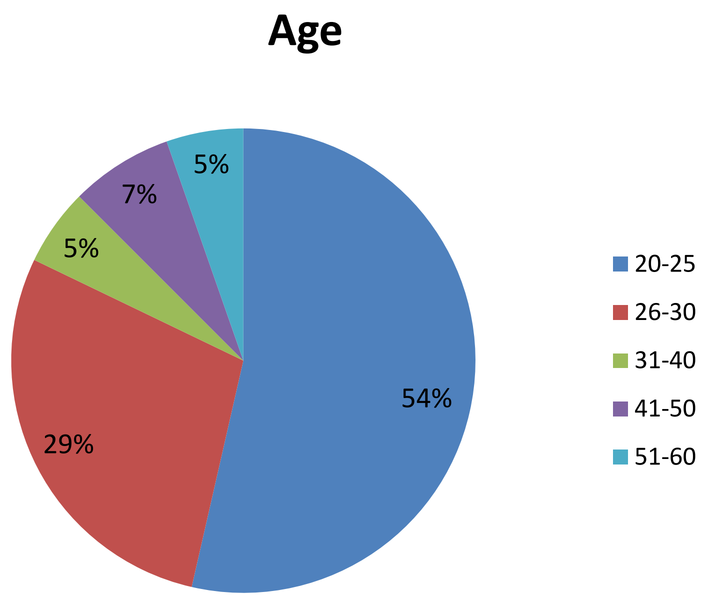


Figure 36. Questionnaire results on age.

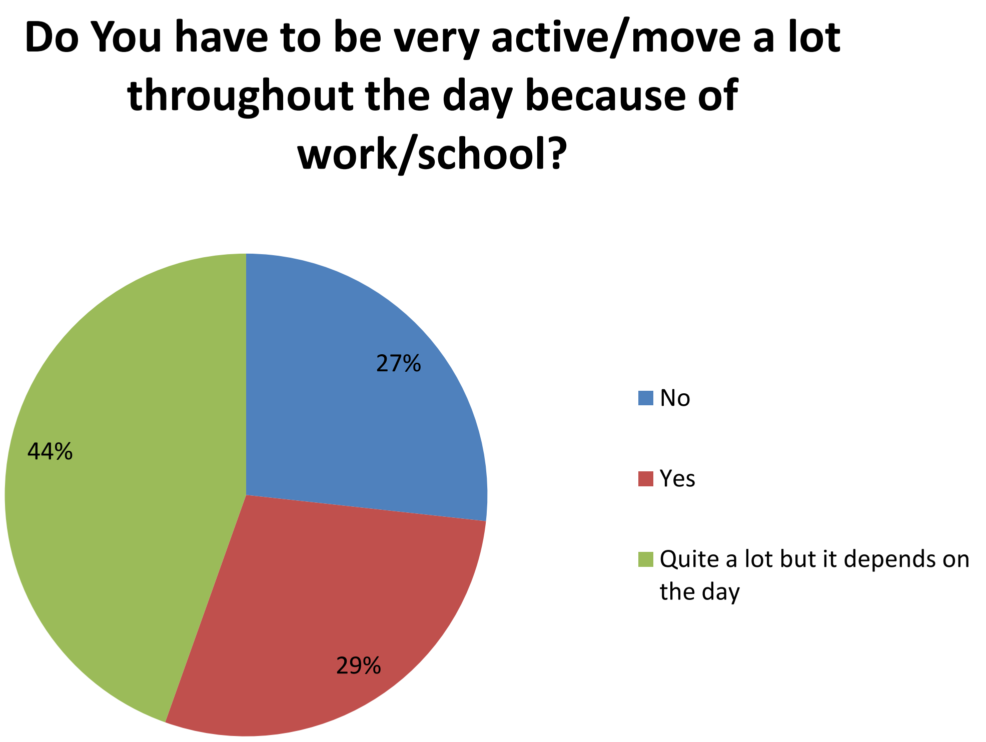


Figure 37. Questionnaire results activity during the day.

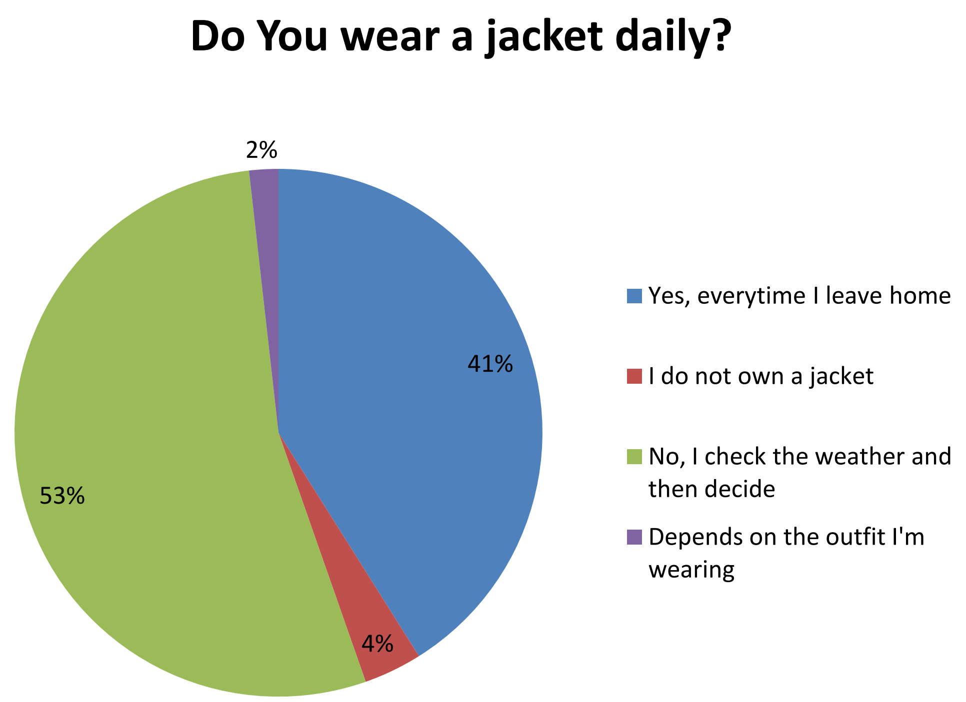


Figure 38. Questionnaire results on jacket wearing frequency.

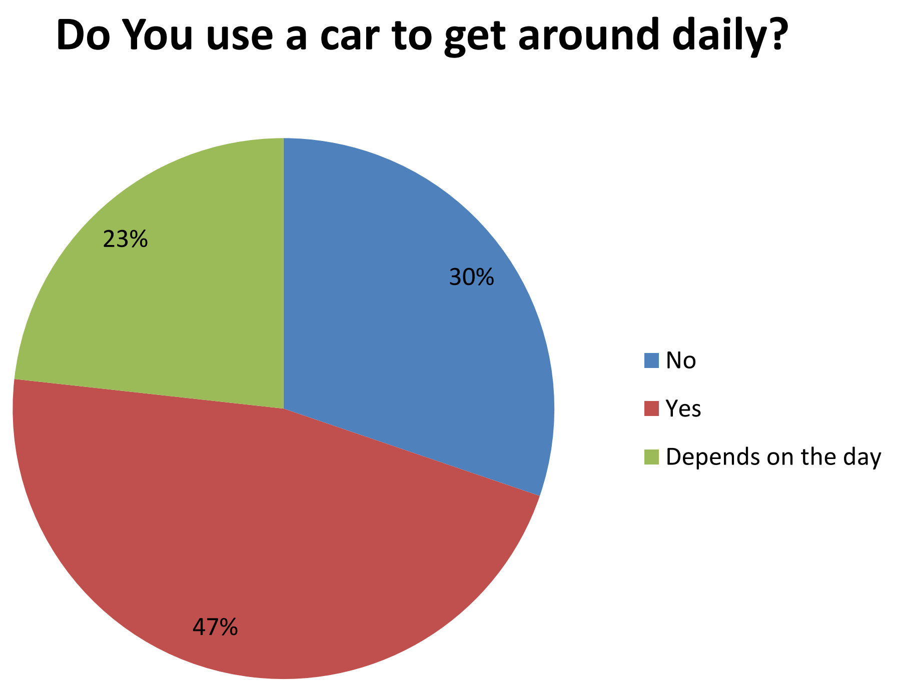


Figure 39. Questionnaire results on car usage.

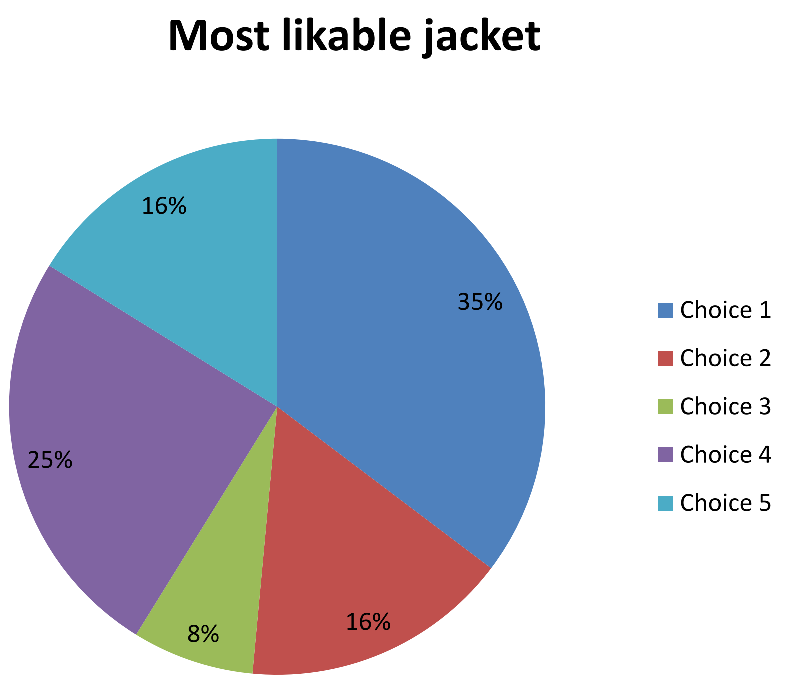


Figure 40. Questionnaire results on most likeable jacket.

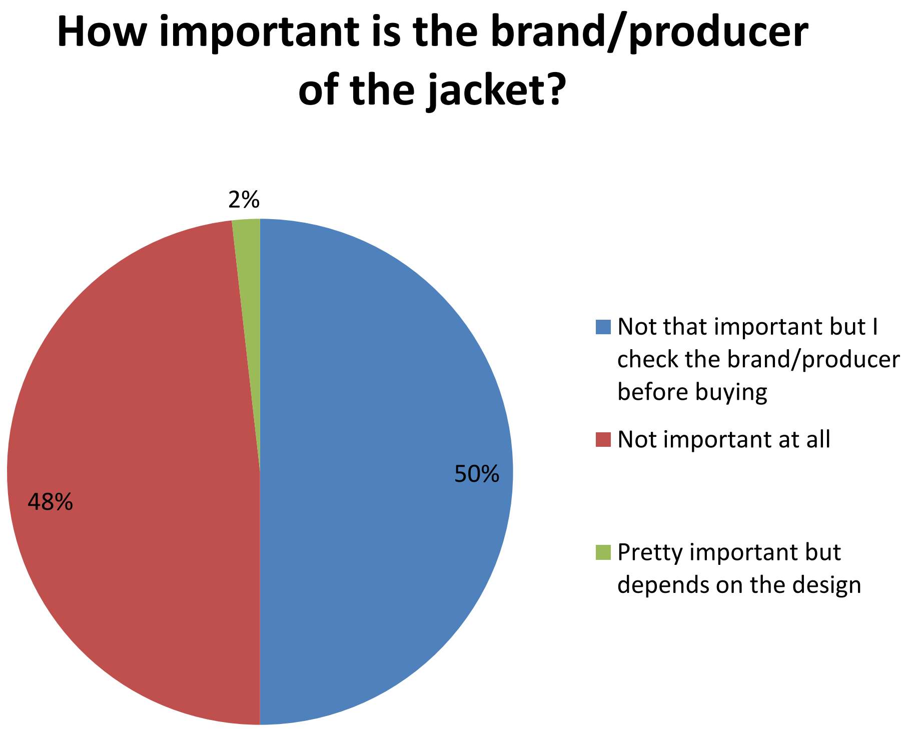


Figure 41. Questionnaire results on brand importance.

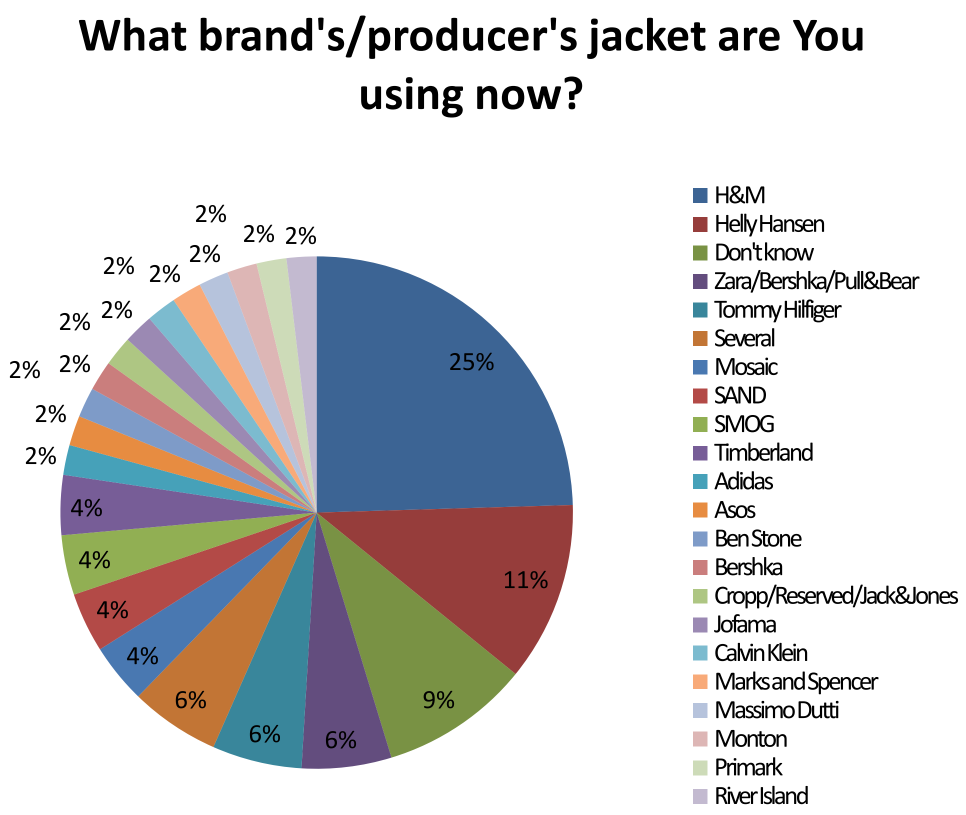


Figure 42. Questionnaire results on which brand is most popular.

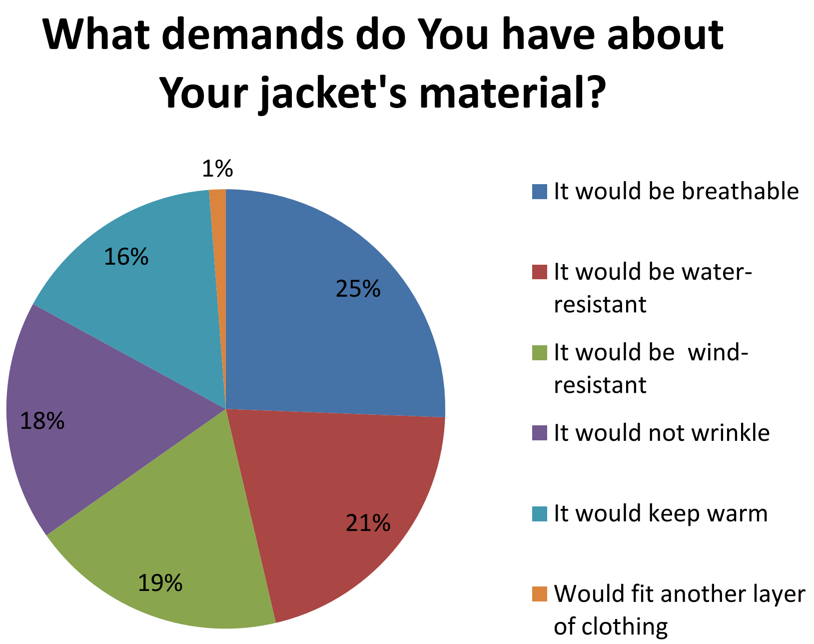


Figure 43. Questionnaire results on demands to jacket material.

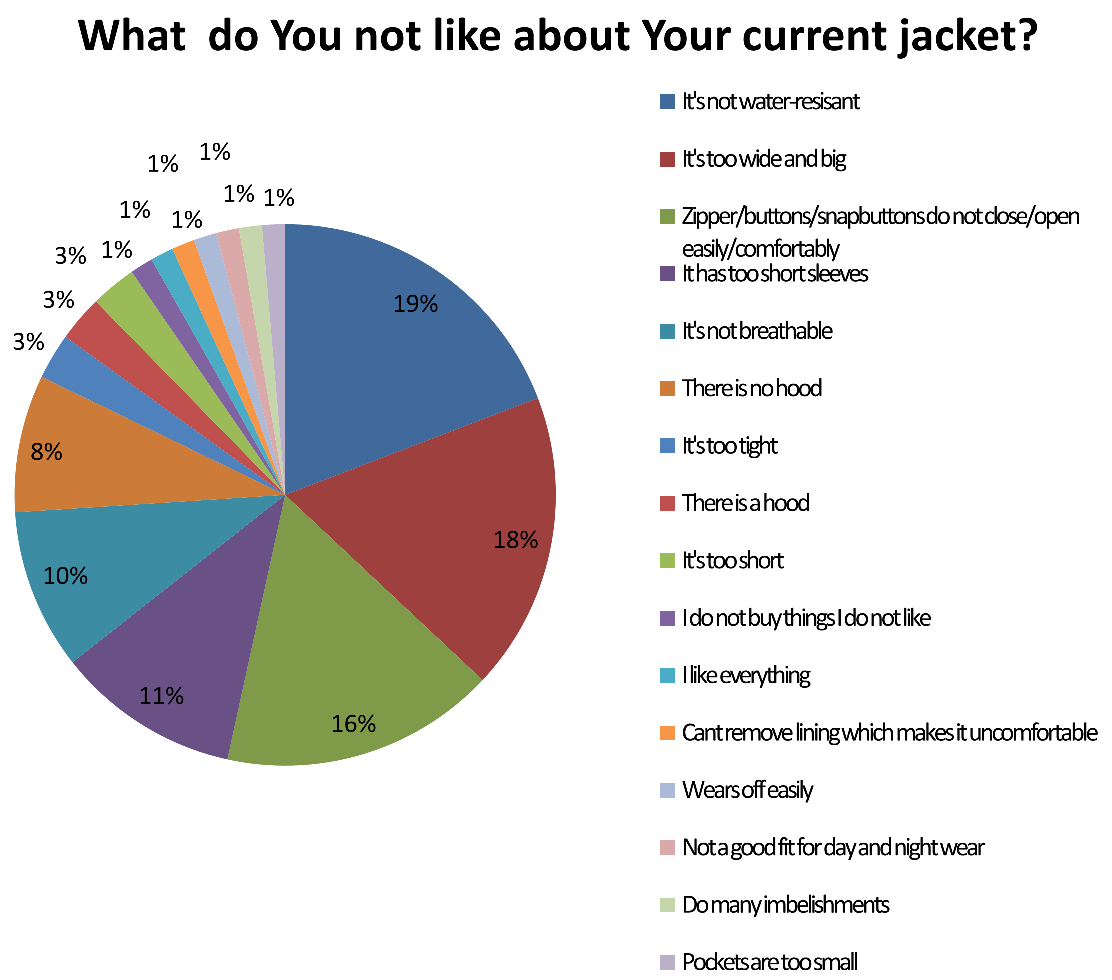


Figure 44. Questionnaire results on dislikes about current jacket.

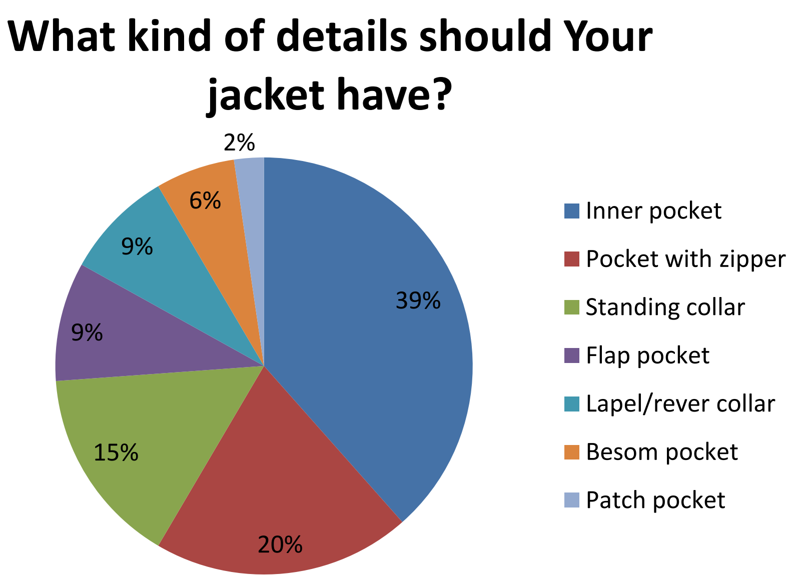


Figure 45. Questionnaire results on which details are wanted on a jacket.

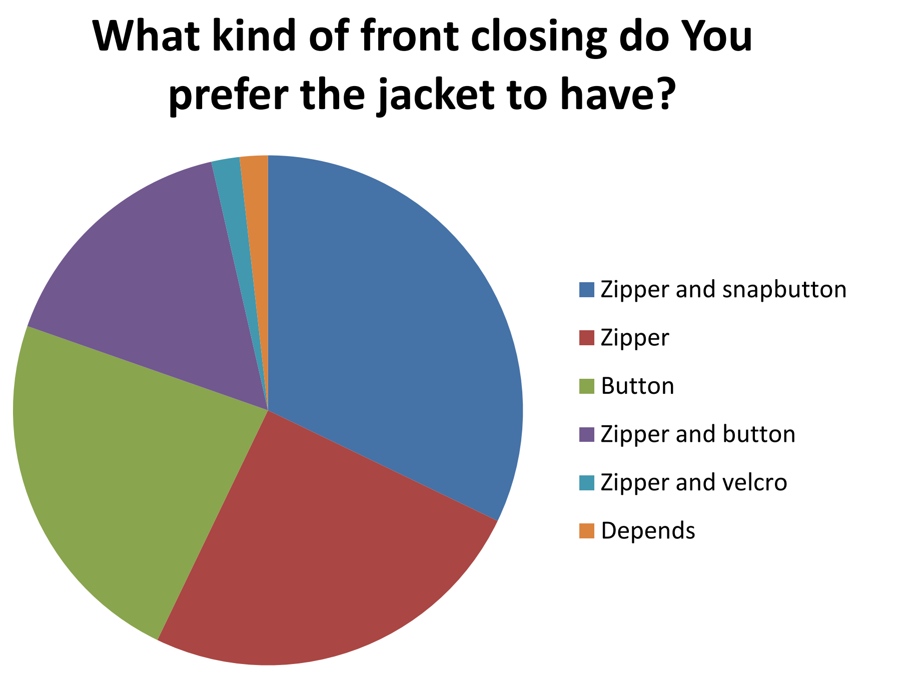


Figure 46. Questionnaire results on front closing preferances.

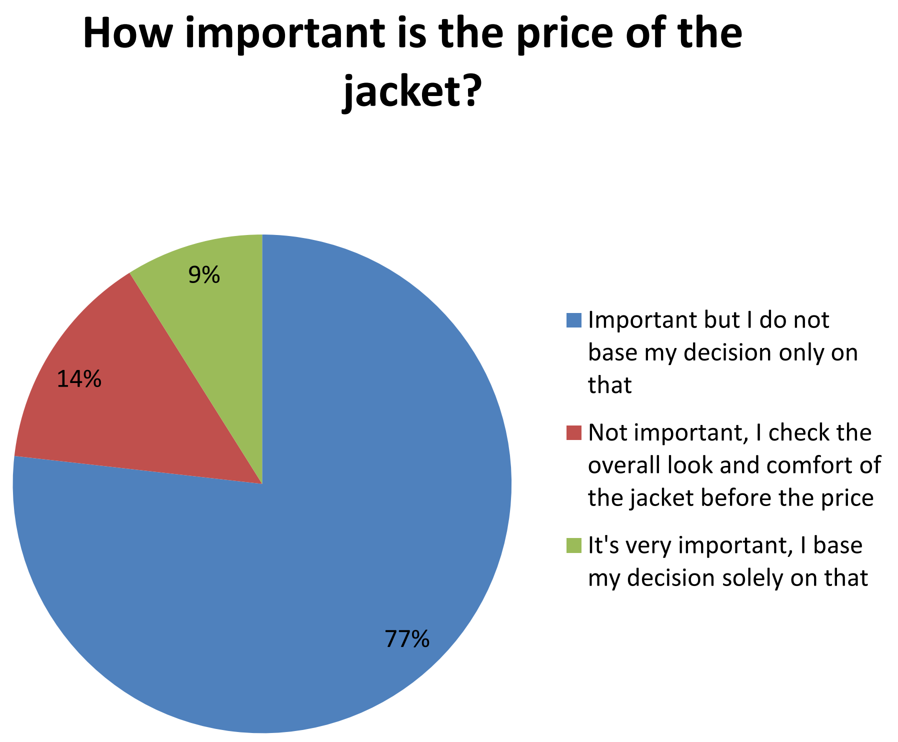


Figure 47. Questionnaire results on price importance.

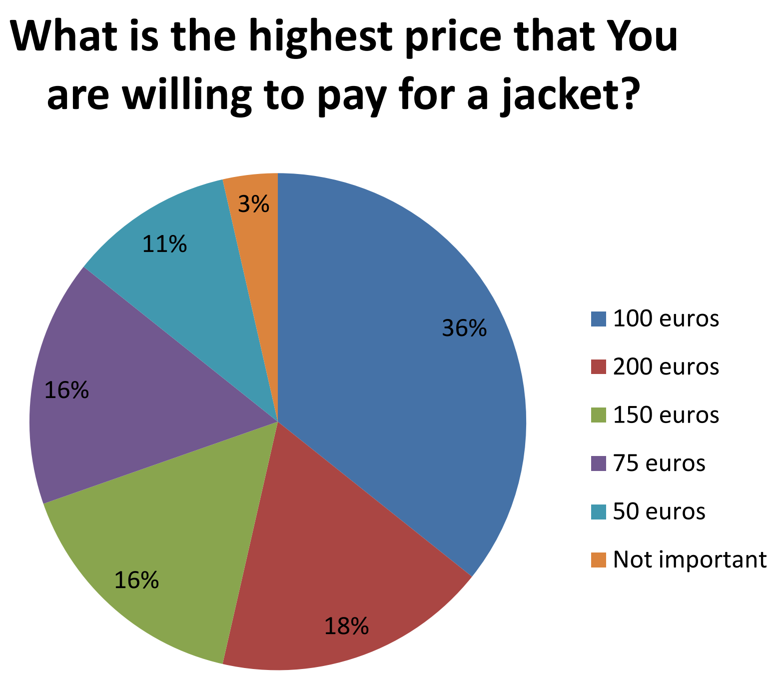


Figure 48. Questionnaire results on price.

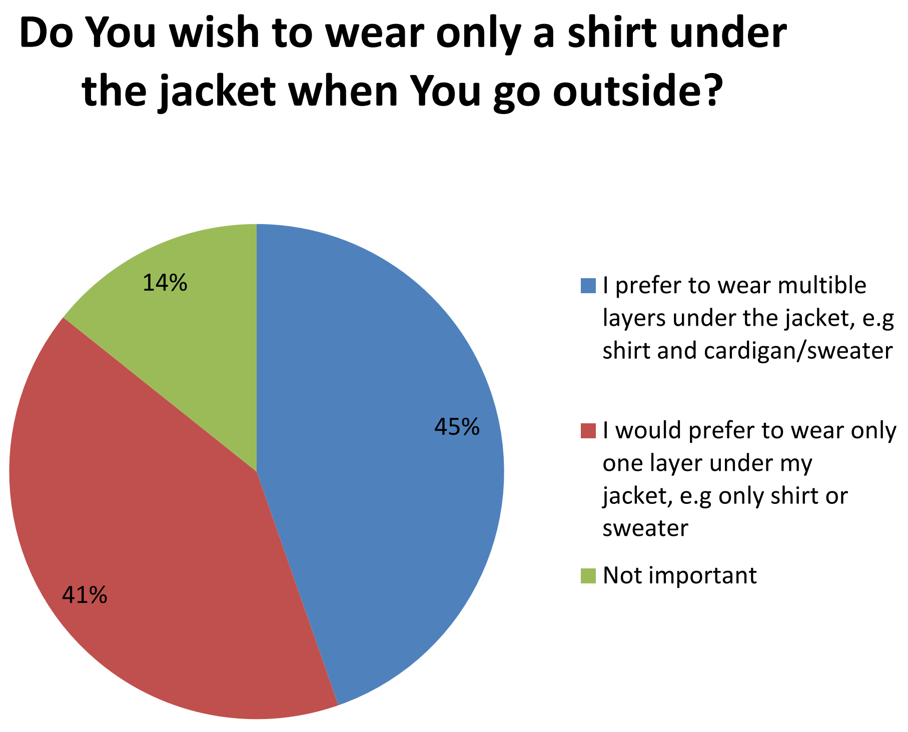
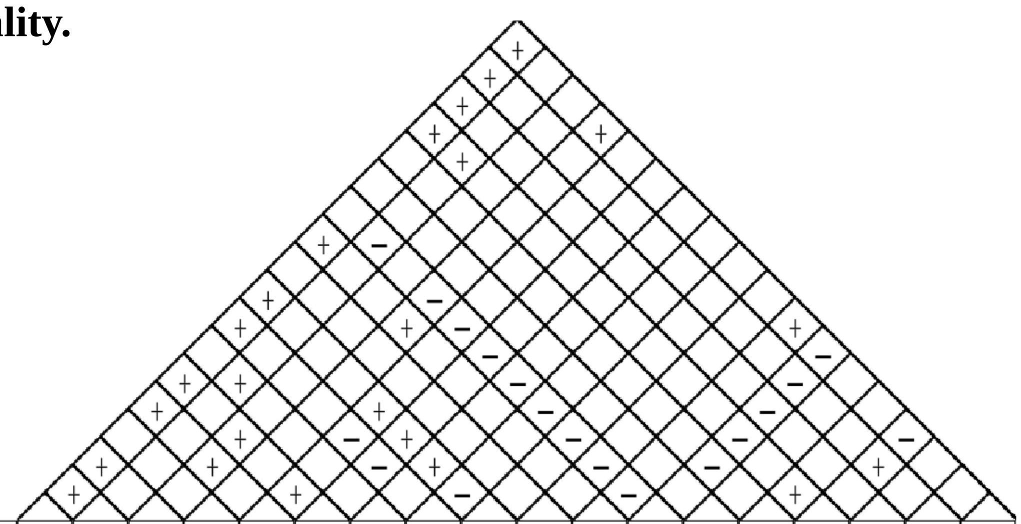


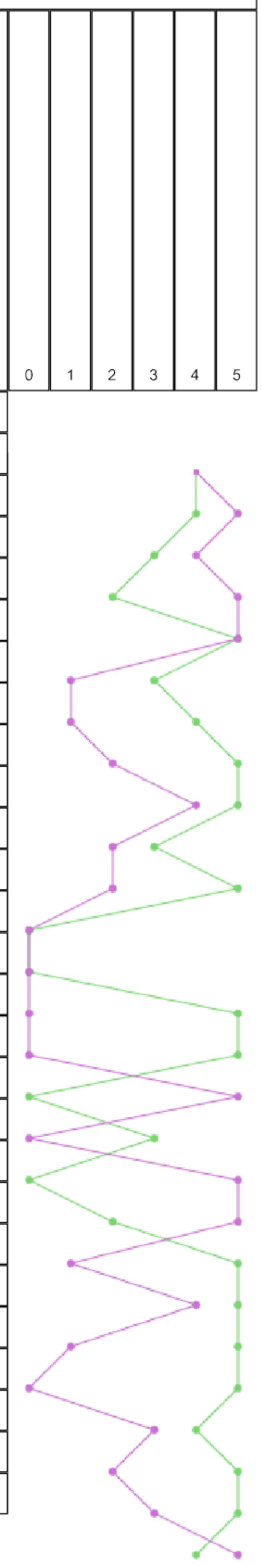
Figure 49. Questionnaire results on layering importance and preferences.

APPENDIX 4. House of Quality.



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality	Products function/purpose	Products esthetic look and simplicty	Product's life expectancy	Precence of inner chest pocket	Water-resistant main material	Wind-resistant main material	Center-front closing with zipper and buttons/snapbuttons	Breathable main material	Thermal clothing	Non-wrinkly main material	Pockets with zippers	Produc's price	Standing collar type	Sleeves' length	Fit of the product	Precence of a hood	Length of the product	Number of pockets	Reserved jacket	Timberland jacket
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
				Direction of Improvement			▲		▲	▲		▲				▼		▲			▲	▲		
1	9	5.2%	5	Universal style	Θ	Θ	▲	O	O	O	O	O	O	O	O	O	O	▲	▲	O	O	O	4	4
2	9	5.2%	5	Esthetic look at work and on free-time	Θ	Θ	▲	▲	O	O	O	O	▲	O	O	▲	O	O	Θ	O	O	O	4	5
3	9	5.2%	5	Simplicity of the product's style	O	Θ	▲	▲	▲	▲	O	▲	▲	▲	O	O	O	▲	▲	O	▲	Θ	3	4
4	9	5.2%	5	Product would last long	O	▲	Θ	▲	Θ	O	▲	O	O	▲	O	Θ	▲	▲	▲	▲	▲	▲	2	5
5	9	5.2%	5	Precence of inner chest pocket	▲	O	▲	Θ	▲	▲	▲	▲	▲	▲	O	O	▲	▲	▲	▲	Θ	Θ	5	5
6	9	5.2%	5	Water-resistant	Θ	O	Θ	▲	Θ	O	▲	O	Θ	O	O	Θ	O	O	▲	O	O	▲	3	1
7	9	5.2%	5	Wind-resistant	Θ	O	Θ	▲	O	Θ	▲	O	Θ	O	O	Θ	O	O	▲	O	O	▲	4	1
8	9	5.2%	5	Center-front closing with zipper and buttons/snapbuttons	O	Θ	O	▲	▲	▲	Θ	▲	O	▲	▲	Θ	▲	▲	O	▲	▲	▲	5	2
9	9	5.2%	5	Breathable	Θ	▲	O	▲	O	O	▲	Θ	Θ	O	O	Θ	▲	▲	▲	▲	▲	▲	5	4
10	9	4.1%	4	Thermal clothing	Θ	▲	O	▲	O	O	▲	O	Θ	▲	O	Θ	▲	O	▲	O	O	▲	3	2
11	9	4.1%	4	Not wrinkly	O	O	O	▲	O	O	▲	O	O	Θ	▲	O	▲	▲	▲	▲	O	▲	5	2
12	9	4.1%	4	Pockets with zippers	▲	Θ	O	▲	▲	▲	▲	▲	▲	▲	Θ	O	▲	▲	▲	▲	▲	Θ	0	0
13	9	4.1%	4	Product price 100 - 150 euros	▲	▲	▲	O	O	O	O	O	O	O	O	Θ	O	O	O	O	O	O	0	0
14	9	3.1%	3	Standing collar	▲	O	O	▲	▲	▲	▲	▲	▲	▲	▲	O	Θ	▲	O	▲	▲	▲	5	0
15	9	3.1%	3	Product price 50-99 euros	▲	▲	▲	O	O	O	O	O	O	O	O	Θ	O	O	O	O	O	O	5	0
16	9	3.1%	3	Product price 151-200 euros	▲	▲	▲	O	O	O	O	O	O	O	O	Θ	O	O	O	O	O	O	0	5
17	9	3.1%	3	Center-front closing with zipper	O	Θ	O	▲	▲	▲	O	▲	O	▲	▲	O	▲	▲	O	▲	▲	▲	3	0
18	3	3.1%	3	Rever/lapel collar	O	O	O	▲	▲	▲	O	▲	O	▲	▲	O	O	▲	O	O	▲	▲	0	5
19	9	3.1%	3	Center-front closing with buttons	O	Θ	O	▲	▲	▲	O	▲	O	▲	▲	O	▲	▲	O	▲	▲	▲	2	5
20	9	3.1%	3	Comfortable, quick and smooth way to put the product on	O	O	▲	▲	▲	▲	Θ	▲	▲	▲	▲	▲	▲	▲	O	▲	O	▲	5	1
21	9	3.1%	3	Long enough sleeves	O	O	▲	▲	O	O	▲	O	O	▲	▲	O	▲	Θ	O	▲	▲	▲	5	4
22	9	3.1%	3	Good fit	Θ	Θ	O	▲	▲	▲	Θ	▲	▲	▲	▲	▲	▲	Θ	Θ	O	Θ	O	5	1
23	9	2.1%	2	Precence of a hood	O	O	O	▲	O	O	▲	O	O	▲	▲	O	▲	▲	O	Θ	▲	▲	5	0
24	3	2.1%	2	Good ratio of the price and quality	▲	▲	▲	▲	O	O	O	O	▲	▲	▲	O	▲	▲	▲	▲	▲	▲	4	3
25	9	2.1%	2	Product length until hip	O	Θ	O	▲	O	O	▲	O	O	▲	Θ	O	▲	▲	O	▲	Θ	▲	5	2
26	9	2.1%	2	At least 4 pockets	▲	Θ	O	Θ	▲	▲	▲	▲	▲	▲	O	Θ	▲	▲	▲	▲	▲	Θ	5	3
27	9	1%	1	Known manufacturer	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	Θ	▲	▲	▲	▲	▲	▲	4	5

Competitive Analysis



Column #	Target or Limit Value	Difficulty	Max Relationship Value in Column	Weight / Importance	Relative Weight
1	Work and everyday jacket	10	9	442.3	8.5%
2	Esthetic look	10	9	473.2	9.1%
3	Products life expectancy 5 years	8	9	312.4	6%
4	At least 1 chest pocket	2	9	188.7	3.6%
5	Water resistant product	5	9	279.4	5.3%
6	Wind-resistant product	5	9	248.5	4.8%
7	Center-front closing with zipper and buttons	2	9	264.9	5.1%
8	Breathable product	5	9	248.5	4.8%
9	Thermal product until -10 degrees	10	9	349.5	6.7%
10	Non-wrinkly main material	5	9	205.2	3.9%
11	At least 2 pockets with zippers	5	9	264.9	5.1%
12	Product's proce 50-150 euros	10	9	537.1	10.3%
13	Product woth standing collar	2	9	203.1	3.9%
14	none	5	9	209.3	4%
15	Semi-slim fit	10	9	242.3	4.6%
16	Option of a detachable hood	5	9	209.3	4%
17	Length until hip	10	9	267	5.1%
18	4 pockets	5	9	279.4	5.3%

Figure 50. House of Quality.

APPENDIX 5. Patterns for jackets in scale 1/10.

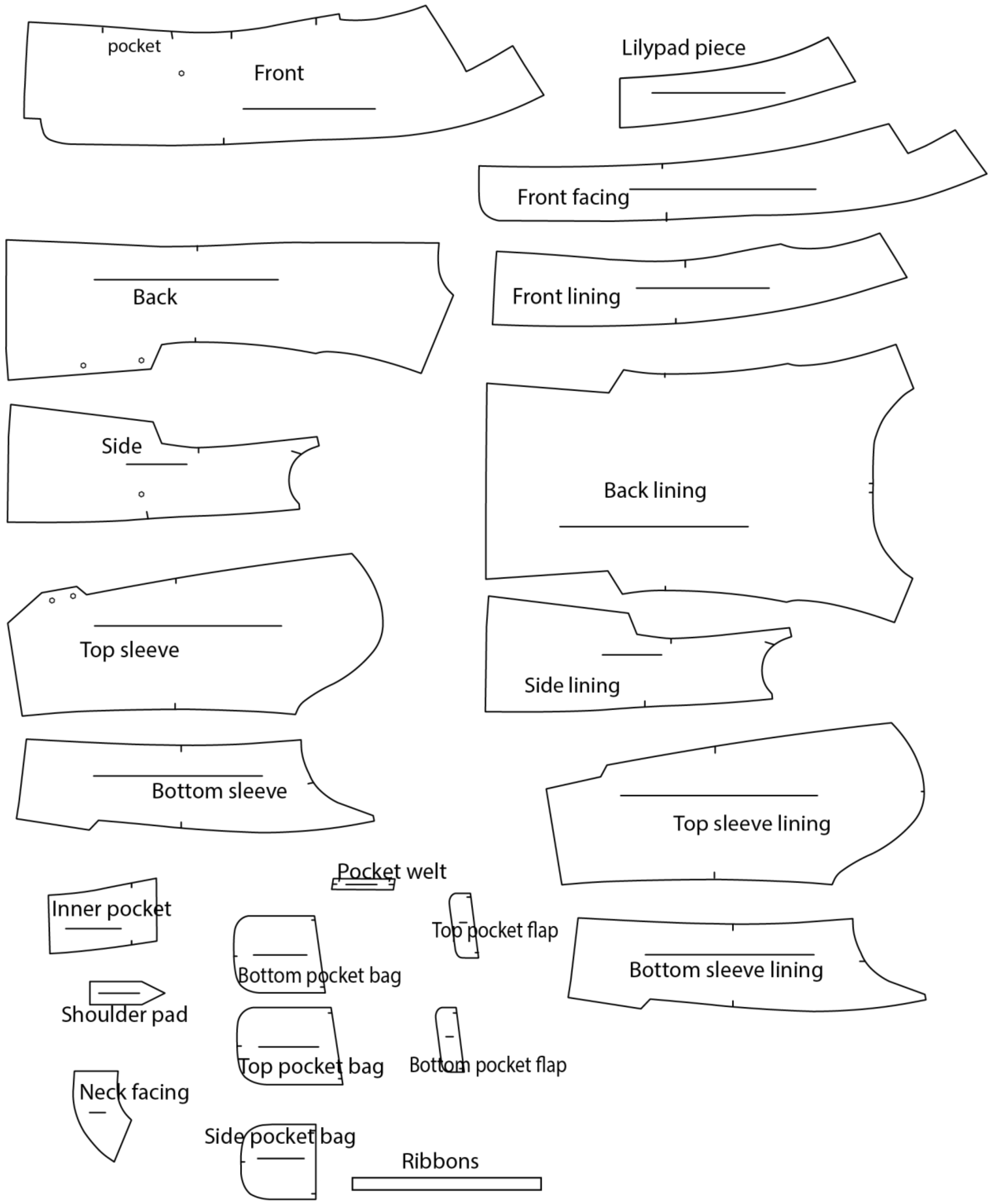


Figure 51. Jacket 1 patterns.

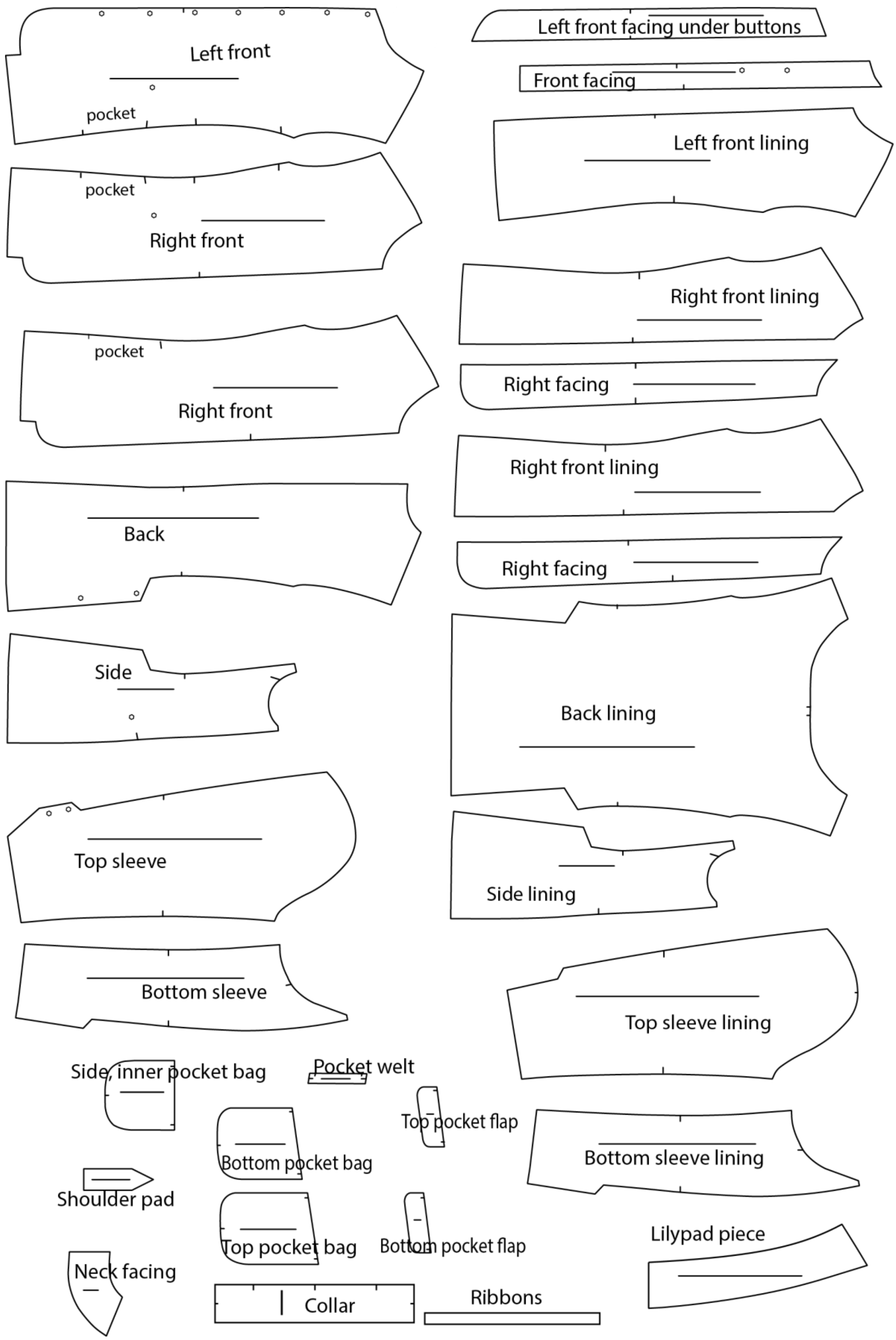


Figure 52. Jacket 2 patterns.

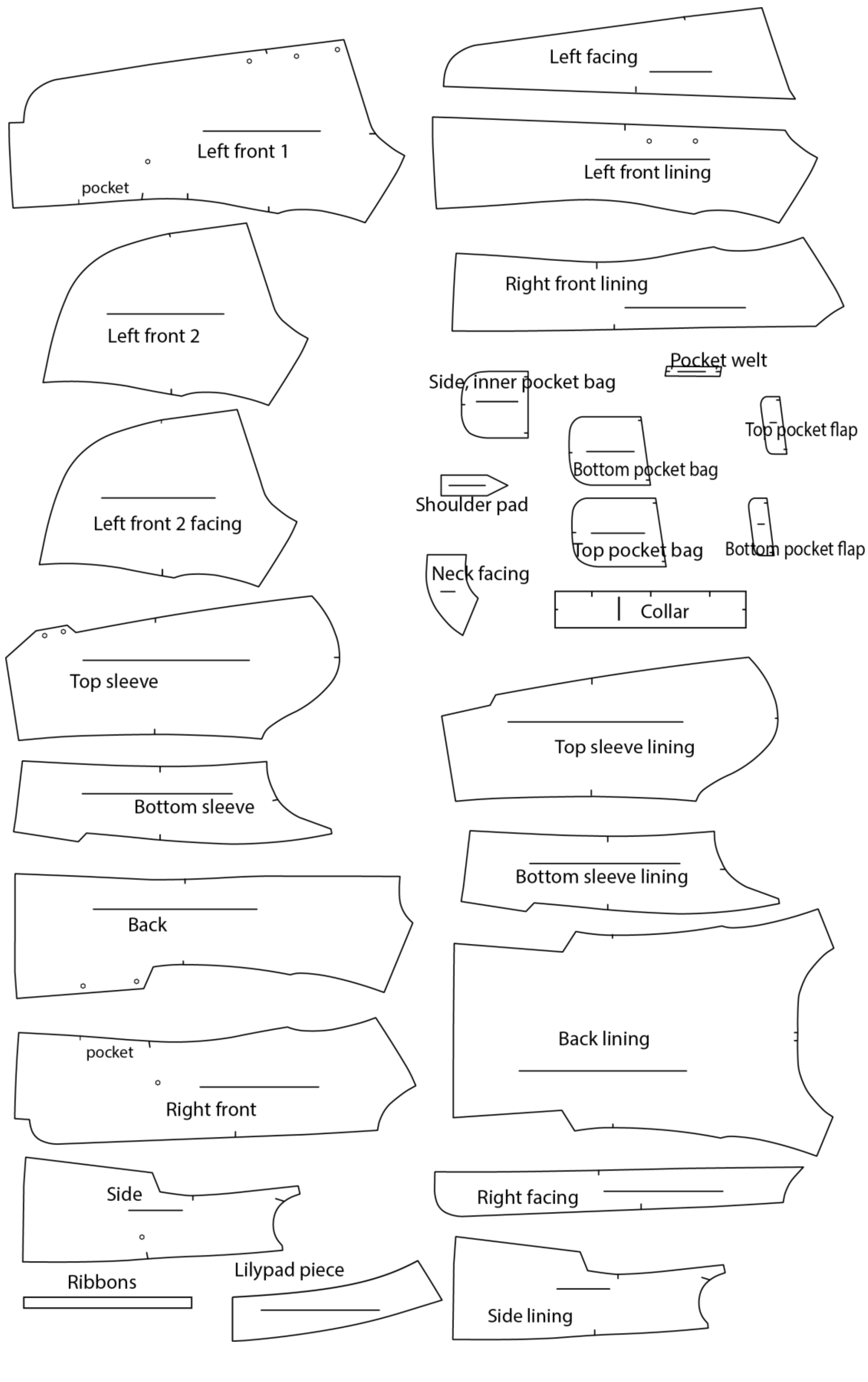


Figure 53. Jacket 3 patterns.

APPENDIX 6. Product cards.

Table 8. Product card of Jacket 1.

PRODUCT CARD					
Model	JACKET 1	**Type**	MEN'S JACKET	**Season**	Spring 2017
Seam allowance 1,0 cm Center-front metal zipper 86,0 cm Front zipper pockets' invisible zippers 12,0 cm Inner invisible zipper 40,0 cm Ribbon length to cut 8,0 cm			Side, bottom sleeve, front and neck facing, top pocket flaps from velour. Sling cord ready length 1,2 m		

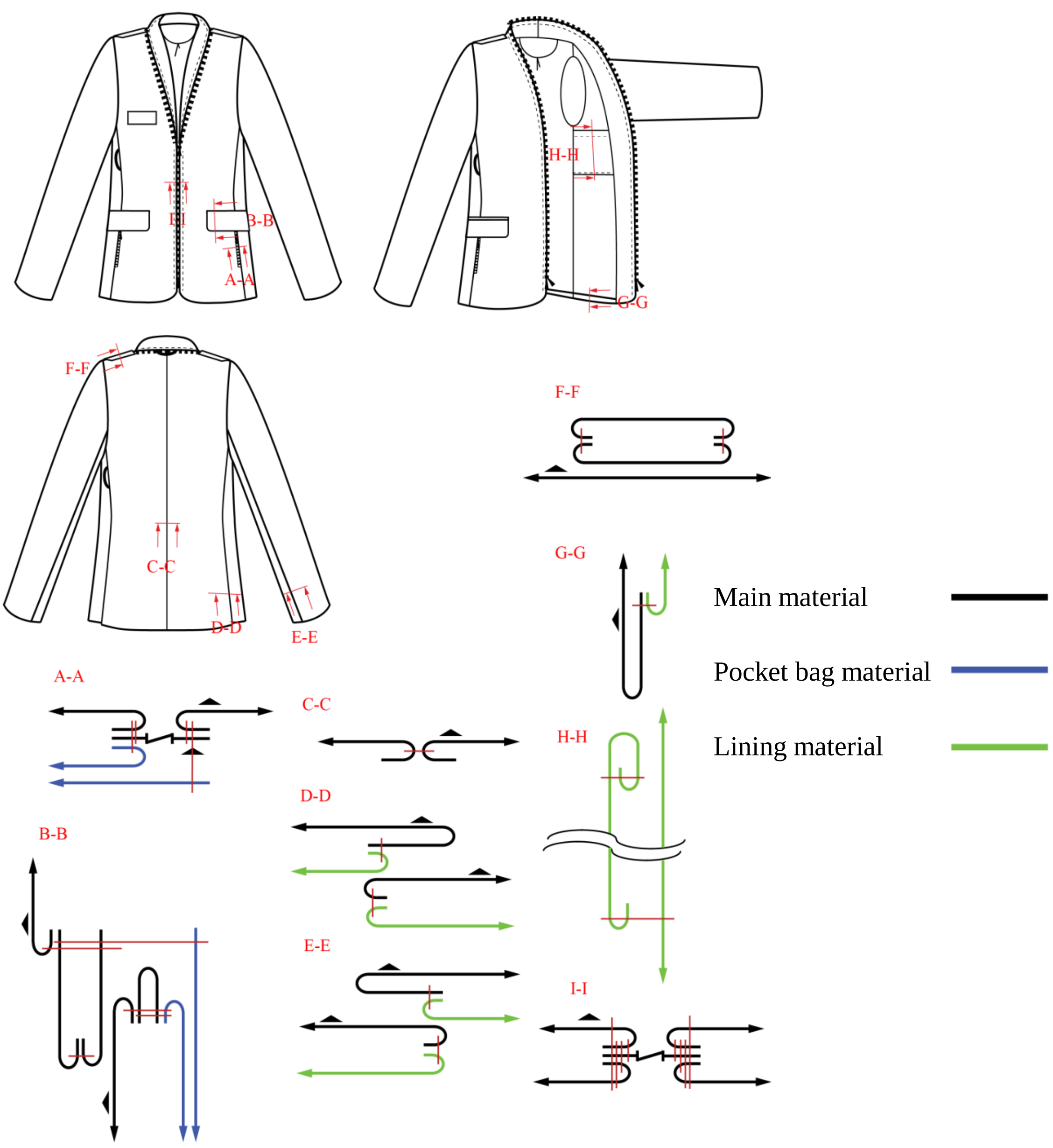


Table 9. Product card of Jacket 2.

PRODUCT CARD					
Model	JACKET 2	**Type**	MEN'S JACKET	**Season**	Spring 2017
Seam allowance 1,0 cm Center-front metal zipper 75,0 cm Zipper pockets' invisible zippers 12,0 cm Inner invisible zipper 40,0 cm Ribbon length to cut 8,0 cm			Side, bottom sleeve, front facings, collar, neck facing, top pocket flap, pocket welt, shoulder pad from velour Sling cord ready length 1,2 m		

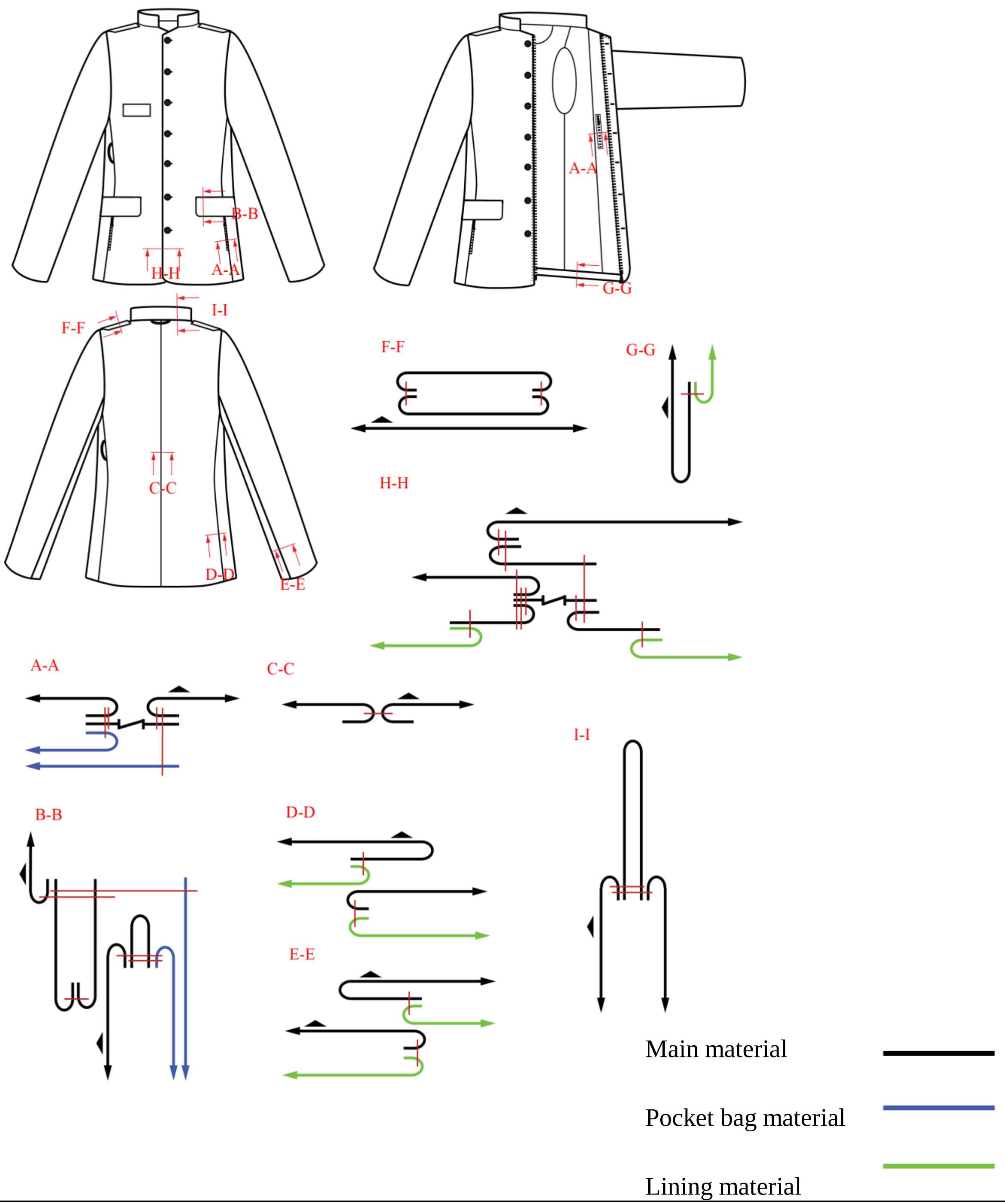
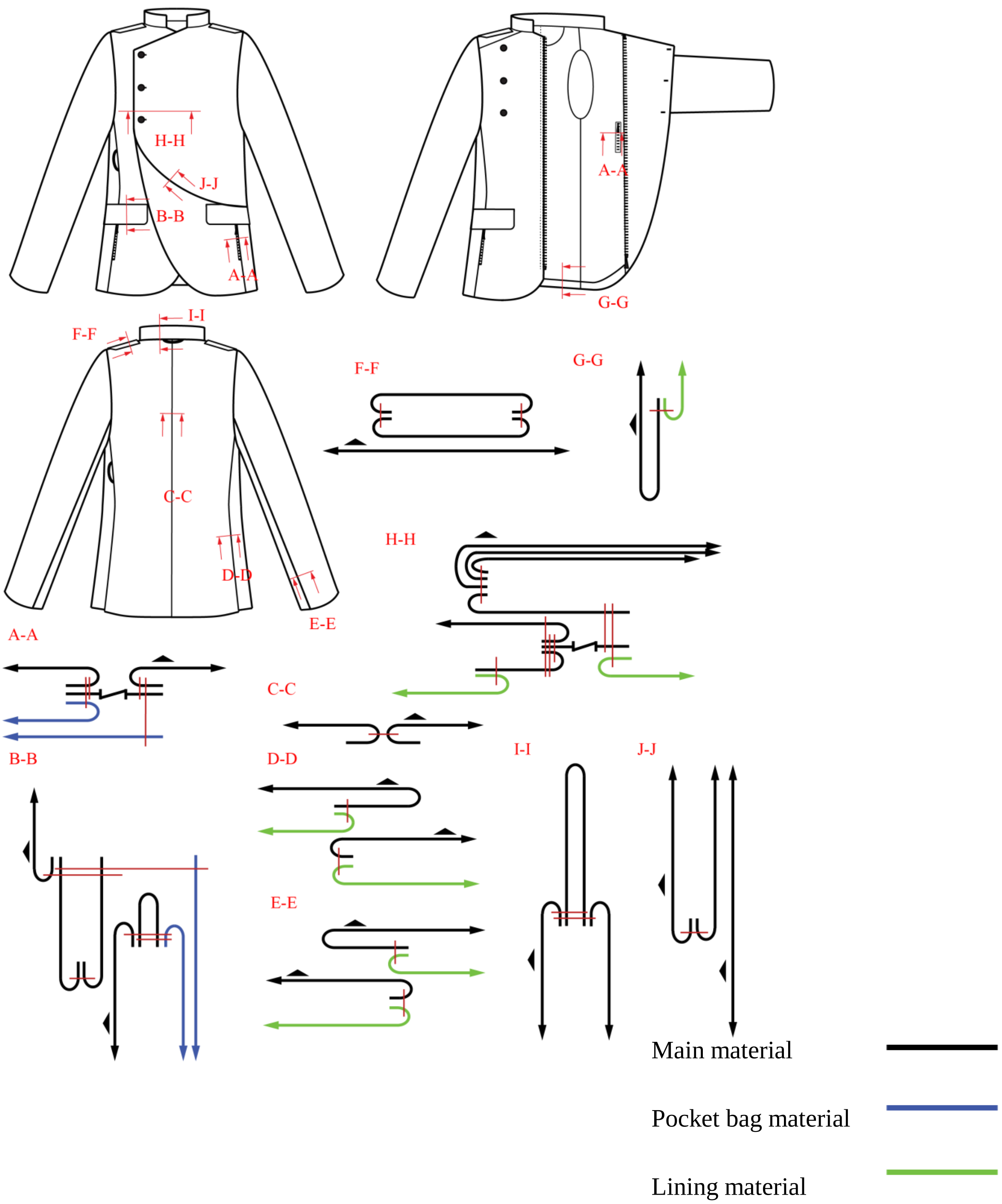


Table 10. Product card of Jacket 3.

PRODUCT CARD					
Model	JACKET 3	**Type**	MEN'S JACKET	**Season**	Spring 2017
Seam allowance 1,0 cm Center-front metal zipper 75,0 cm Zipper pockets' invisible zippers 12,0 cm Inner invisible zipper 40,0 cm Ribbon length to cut 8,0 cm			Side, left front 2, bottom sleeve, front facings, collar, neck facing, top pocket flap, pocket welt, shoulder pad from velour Sling cord ready length 1,2 m		



APPENDIX 7. Bill of materials.

Table 11. Bill of materials with net cost for Jacket 1.

Nr	Item	Description	Amount	Unit	Remark	Price	Unit	Cost per product (€)
1	Main material I	97% PES, 3% PA	2,2	m	Front, back, top sleeve	10	€/m	22
2	Main material II	100% PES	1,2	m		5	€/m	6
3	Main material III	100% PES	0,3	m	Ribbons for sling cord	5	€/m	1,5
4	Lining	100% PES	2,5	m		5	€/m	12,5
5	Pocket bag material	100% CO	0,25	m	Pocket bags, bottom pocket flap, Lilypad piece	3	€/m	0,75
6	Thread	Black 100% PES	220	m	100 tex	0,0009	€/m	0,198
7	Conductive thread	Stainless steel	5	m	Resistance: 28 Ohms/ft	0,4	€/m	2
8	Zipper I	85 cm	1	pc	Center-front	5	€	5
9	Zipper II	Invisible, 12 cm	2	pc	Zipper pockets	0,5	€	1
10	Zipper III	Invisible, 40 cm	1	pc	Opening for Lilypad	0,9	€	0,9
11	Hook loop tape (Velcro)	Conductive	0,5	m	Patches	0,7	€/m	0,35
12	Hook loop tape (Velcro)	Not conductive	0,25	m	Patches	0,2	€/m	0,05
13	Magnetic snap buttons	Nickel	10	pc	Slits	0,5	€	5
14	Patch	100% PES	6	pc		0,4	€	2,4
15	Leather cord with hook	100% leather, zink	1	pc	Sling cord	5	€	5
16	Lilypad ATmega328p Board		1	pc		20	€	20
17	Lilypad Switch		1	pc		7	€	7
18	Lilypad Buzzer		1	pc		7	€	7
19	Lilypad LED-light		1	pc		4	€	4
20	Lilypad Light Sensor		1	pc		5	€	5
21	Hanger		1	pc		0,1	€	0,1
22	Hand tag	Paper	1	pc	With pin	0,1	€	0,1
23	Sticker		2	pc		0,05	€	0,1
24	Plastic bag	50*90 cm	1	pc	Packing	0,05	€	0,05
								108,0

Table 12. Bill of materials with net cost for Jacket 2.

Nr	Item	Description	Amount	Unit	Remark	Price	Unit	Cost per product (€)
1	Main material I	97% PES, 3% PA	2,2	m	Front, back, top sleeve	10	€/m	22
2	Main material II	100% PES	1,2	m		5	€/m	6
3	Main material III	100% PES	1,5	m	Ribbons for sling cord	5	€/m	7,5
4	Lining	100% PES	2,5	m		5	€/m	12,5
5	Pocket bag material	100% CO	0,25	m	Pocket bags, bottom pocket flap, Lilypad piece	3	€/m	0,75
6	Thread	Black 100% PES	230	m	100 tex	0,0009	€/m	0,207
7	Conductive thread	Stainless steel	5	m	Resistance: 28 Ohms/ft	0,4	€/m	2
8	Zipper I	85 cm	1	pc	Center-front	5	€	5
9	Zipper II	Invisible, 12 cm	2	pc	Zipper pockets	0,5	€	1
10	Zipper III	Invisible, 40 cm	1	pc	Opening for Lilypad	0,9	€	0,9
11	Hook loop tape (Velcro)	Conductive	0,5	m	Patches	0,7	€/m	0,35
12	Hook loop tape (Velcro)	Not conductive	0,25	m	Patches	0,2	€/m	0,05
13	Magnetic snap buttons	Nickel	10	pc	Slits	0,5	€	5
14	Patch	100% PES	6	pc		0,4	€	2,4
15	Leather cord with hook	100% leather, zink	1	pc	Sling cord	5	€	5
16	Lilypad ATmega328p Board		1	pc		20	€	20
17	Lilypad Switch		1	pc		7	€	7
18	Lilypad Buzzer		1	pc		7	€	7
19	Lilypad LED-light		1	pc		4	€	4
20	Lilypad Light Sensor		1	pc		5	€	5
21	Hanger		1	pc		0,1	€	0,1
22	Hand tag	Paper	1	pc	Attached to neck facing with pin	0,1	€	0,1
24	Sticker		2	pc		0,05	€	0,05
25	Plastic bag	50*90 cm	1	pc	Packing	0,05	€	0,05
								114,0

Table 13. Bill of materials with net cost for Jacket 3.

Nr	Item	Description	Amount	Unit	Remark	Price	Unit	Cost per product (€)
1	Main material I	97% PES, 3% PA	2,2	m	Left front 1, right front, back, top sleeve	10	€/m	22
2	Main material II	100% PES	1,2	m		5	€/m	6
3	Main material III	100% PES	1,5	m	Ribbons for sling cord	5	€/m	7,5
4	Lining	100% PES	2,5	m		5	€/m	12,5
5	Pocket bag material	100% CO	0,25	m	Pocket bags, bottom pocket flap, Lilypad piece	3	€/m	0,75
6	Thread	Black 100% PES	250	m	100 tex	0,0009	€/m	0,225
7	Conductive thread	Stainless steel	5	m	Resistance: 28 Ohms/ft	0,4	€/m	2
8	Zipper I	85 cm	1	pc	Center-front	5	€	5
9	Zipper II	Invisible, 12 cm	2	pc	Zipper pockets	0,5	€	1
10	Zipper III	Invisible, 40 cm	1	pc	Opening for Lilypad	0,9	€	0,9
11	Hook loop tape (Velcro)	Conductive	0,5	m	Patches	0,7	€/m	0,35
12	Hook loop tape (Velcro)	Not conductive	0,25	m	Patches	0,2	€/m	0,05
13	Magnetic snap buttons	Nickel	10	pc	Slits	0,5	€	5
14	Patch	100% PES	6	pc		0,4	€	2,4
15	Leather cord with hook	100% leather, zink	1	pc	Sling cord	5	€	5
16	Lilypad ATmega328p Board		1	pc		20	€	20
17	Lilypad Switch		1	pc		7	€	7
18	Lilypad Buzzer		1	pc		7	€	7
19	Lilypad LED-light		1	pc		4	€	4
20	Lilypad Light Sensor		1	pc		5	€	5
21	Hanger		1	pc		0,1	€	0,1
22	Hand tag	Paper	1	pc	Attached to nech facing with pin	0,1	€	0,1
24	Sticker		2	pc		0,05	€	0,05
25	Plastic bag	50*90 cm	1	pc	Packing	0,05	€	0,05
								114,0

APPENDIX 8. Sewing technology.

Table 14. Jacket 1 sewing technology

JACKET 1 SEWING TECHNOLOGY	
Nr	**Sewing operation**
OUTER LAYER	
1	Sewing velcro strips on the shoulder pads and chest pieces
2	Sewing the shoulder pads and chest pieces from inside
3	Sewing ribbons
4	Sewing forepart and side body by adding a ribbon to right seam
Zipper pockets twice:	
5	Sewing vertically the zipper and the pocket bags for side pocket
6	Cutting the side pocket open
7	Sewing the triangle from the top and bottom edges to pocket bags
8	Sewing the pocket bags together
Flap pockets twice:	
9	Sewing the pocket flaps from inside
10	Sewing the flaps and welts together
11	Sewing the pocket flaps and welts to jacket
12	Sewing the pocket bags to jacket
13	Cutting the opening to flap pockets
14	Sewing the triangle in the pocket edges (inside)
15	Sewing the pocket bags together
16	Sewing the center back
17	Sewing the back part and side body by adding a ribbon to left seam
18	Sewing the shoulder line
19	Sewing velcro strips on the main material on chest and on shoulder
20	Sewing the neckline by adding the ribbon to center-back
21	Sewing the front-zipper to the product
22	Sewing the front facing to the product
23	Sewing the seam allowences to the front-facing
24	Sewing through front and front facing, 0,7 cm fron center-front
25	Sewing the sleeve details
26	Sewing the sleeves to jacket
LINING	
27	Sewing the neckline welt to neckline
28	Sewing inner pockets upper edge 2+2 cm
29	Sewing inner pocket to the front lining from lower edge 0,1 cm
30	Sewing the inner pocket to side seam allowences
31	Sewing the lining details
32	Sewing the lining to front facing and neck welt
33	Sewing the zipper between right front lining and facing

Table 14. Jacket 1 sewing technology

JACKET 1 SEWING TECHNOLOGY	
Nr	**Sewing operation**
34	Sewing the sleeve hems to outer layer
35	Sewing the lining to the outer layer hem
36	Attaching outer layer and lining from back neckline, scye top with a ribbon
37	Sewing magnetic snap buttons to the slits
38	Sewing paches to shoulder pads and chest piece

Table 15. Jacket 2 sewing technology

JACKET 2 SEWING TECHNOLOGY	
Nr	**Sewing operation**
OUTER LAYER	
1	Sewing velcro strips on the shoulder pads and chest pieces
2	Sewing the shoulder pads and chest pieces from inside
3	Sewing ribbons
4	Sewing forepart and side body by adding a ribbon to right seam
Zipper pockets twice:	
5	Sewing vertically the zipper and the pocket bags for side pocket
6	Cutting the side pocket open
7	Sewing the triangle from the top and bottom edges to pocket bags
8	Sewing the pocket bags together
Flap pockets twice:	
9	Sewing the pocket flaps from inside
10	Sewing the flaps and welts together
11	Sewing the pocket flaps and welts to jacket
12	Sewing the pocket bags to jacket
13	Cutting the opening to flap pockets
14	Sewing the triangle in the pocket edges (inside)
15	Sewing the pocket bags together
16	Sewing the center back
17	Sewing the shoulder line
18	Sewing velcro strips on the main material on chest and on shoulder
19	Sewing the back part and side body by adding a ribbon to left seam
21	Sewing the front facing for buttons to the product
22	Sewing the seam allowences to the front-facing for buttons 0,1 cm
23	Sewing the front-zipper to right front piece and left front facing
24	Sewing the front facing to the product
25	Sewing collar edges
26	Sewing collar to the neckline by adding the ribbon to center-back
27	Sewing the sleeve details

Table 15. Jacket 2 sewing technology

JACKET 2 SEWING TECHNOLOGY	
Nr	**Sewing operation**
OUTER LAYER	
28	Sewing the sleeves to jacket
LINING	
29	Sewing vertically the zipper and the pocket bags for side pocket
30	Cutting the side pocket open
31	Sewing the triangle from the top and bottom edges to pocket bags
32	Sewing the pocket bags together
33	Sewing the neckline welt to neckline
34	Sewing the lining details
35	Sewing the lining to front facing and neck welt
36	Sewung the zipper between right front lining and facing
37	Sewing the sleeve hems to outer layer
38	Sewing the lining to the outer layer hem
39	Attaching outer layer and lining from back neckline, scye top with a ribbon
40	Sewing the buttonholes to the product
41	Sewing buttons to the product
42	Sewing magnetic snap buttons to the slits
43	Sewing paches to shoulder pads and chest piece

Table 16. Jacket 3 sewing technology

JACKET 3 SEWING TECHNOLOGY	
Nr	**Sewing operation**
OUTER LAYER	
1	Sewing velcro strips on the shoulder pads
2	Sewing the shoulder pads from inside
3	Sewing ribbons
4	Sewing forepart and side body by adding a ribbon to right seam
Zipper pockets twice:	
5	Sewing vertically the zipper and the pocket bags for side pocket
6	Cutting the side pocket open
7	Sewing the triangle from the top and bottom edges to pocket bags
8	Sewing the pocket bags together
Flap pockets twice:	
9	Sewing the pocket flaps from inside
10	Sewing the flaps and welts together
11	Sewing the pocket flaps and welts to jacket
12	Sewing the pocket bags to jacket
13	Cutting the opening to flap pockets
14	Sewing the triangle in the pocket edges (inside)

Table 16. Jacket 3 sewing technology

JACKET 3 SEWING TECHNOLOGY	
Nr	**Sewing operation**
OUTER LAYER	
15	Sewing the pocket bags together
16	Sewing the center back
17	Sewing the shoulder line
18	Sewing velcro strips on the main material on chest and on shoulder
19	Sewing the back part and side body by adding a ribbon to left seam
20	Sewing front part 2 and it's facing
21	Sewing the seam allowences to the front facing 2
22	Making button holes to the front part 2
23	Sewing the front part 2 to the product from back side seams, front armhole, shoulder and front edge
24	Sewing the front-zipper to right front piece and left front facing
25	Sewing the front facing to the product
26	Sewing collar edges
27	Sewing collar to the neckline by adding the ribbon to center-back
28	Sewing the sleeve details
29	Sewing the sleeves to jacket
LINING	
30	Sewing vertically the zipper and the pocket bags for side pocket
31	Cutting the side pocket open
32	Sewing the triangle from the top and bottom edges to pocket bags
33	Sewing the pocket bags together
34	Sewing the neckline welt to neckline
35	Sewing the lining details
36	Sewing the lining to front facing and neck welt
37	Sewung the zipper between right front lining and facing
38	Sewing the sleeve hems to outer layer
39	Sewing the lining to the outer layer hem
40	Sewing the buttonholes to the product
41	Sewing buttons to the product
42	Sewing magnetic snap buttons to the slits
43	Sewing paches to shoulder pads and chest piece

APPENDIX 9. Picturesof prototype.

Figure 54. Prototype from the front.

Figure 55. Prototype from the front.

Figure 56. Prototype worn with straps.

Figure 57. Prototype worn sitting down.

Figure 58. Prototype from the front.