Roadmap for boosting the international growth of Finnish clothing and textile industry

Part 1. Potential of digital transformation for Finnish clothing and textile industry

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1. Introduction

This deliverable document is part of the ‘Competitiveness from digitalisation in clothing industry’ (DICI) project partially funded by Tekes – the Finnish Funding Agency for Technology and Innovation. An overall objective of the DICI project is to enhance the global competitiveness and appeal of the Finnish clothing and textile industry by exploiting digitalisation and technological advances.

This deliverable explores a potential of digital transformation for the Finnish clothing and textile industry. The progress of new technologies and digitalisation-based concepts in the international clothing and textile context are continuously monitored in the DICI project. A specific goal of the project is to identify disruptive technologies and business models that have a major effect on the transformation and analyse their potential for the Finnish industry. This deliverable introduces technologies that have a potentially significant impact on digitalisation of a textile and clothing domain.

Digital transformation related to Finnish clothing and textile industry are examined through the study conducted in the DICI project. Besides review of the current literature and available services, data was collected from textile and clothing companies through the online questionnaire and interviews. Collected data was analysed for studying the current situation, challenges, opportunities and future visions of the Finnish companies regarding digital solutions and consequently deepen our understanding of the potential of digital transformation in the Finnish clothing and textile industry.

As described above, results presented in this deliverable document are based on the literature review and survey and interviews targeted at the Finnish clothing and textile industry. A wide range of different types of companies from that sector participated in the study. Based on the results the aim is to define the impacts of digitalisation and new business opportunities specifically suitable for Finnish industry and present a roadmap that can be utilised by companies for planning the next steps on their path to digitalisation. This document presents results from the first project period. The document will be enhanced during the second phase of the project in 2018.

This document is structured as follows: Section 2 presents the selected topics of emerging technologies which have been highlighted in research and innovations in the clothing and textile sector during recent years. Section 3 describes the findings from the company questionnaire and interviews. Section 4 focus on future insights into the Finnish clothing and textile industry and outlines the first version of the roadmap for utilising digitalisation.
2. State-of-Art on selected topics of emerging technologies

This section gives an overview of the selected new technology-enabled solutions and services that have recently emerged in the research, innovation and development activities regarding the clothing and textile industry. Topics presented in this section are identified by going through articles and books discussing new technologies and the clothing and textile industry. In addition, different types of digital services offered by companies were overviewed via online search.

2.1 Digital customisation services

This section outlines the current state of customisation services in the textile and clothing industry.

2.1.1 Overview

Products and services utilising customisation and especially mass customisation have gained an increasing interest during recent decades and there is notable amount of research on the mass customisation. The word customise means traditionally to modify (something) according to a customer's individual requirements. In general, today's customers are seeking more personalised products and services and manufacturers and service providers are aiming to satisfy customer needs, desires and preferences by providing different types of service interfaces for customisation and developing their production processes to support customisation of products. Customisation and mass customisation are trends that have raised interest in many industries, such as the automotive, food and apparel industries. The concept of mass customisation was first introduced by Toffler (1971) in “Future shock” and later coined by Davis (1987) in a book titled “Future perfect”. Tseng and Piller (2003) summarise the objective of mass customisation as follows:

“…to deliver goods and services that meet individual customers’ needs with near mass production efficiency.” (Tseng & Piller, 2003, p. 7)

Barman and Canizares (2015) highlights the role of computer-aided manufacturing systems in their definition of mass customisation as follows:

“Mass Customization (MC), within the marketing, manufacturing, and management contexts of an organization, is the use of flexible, computer-aided manufacturing systems to produce custom outputs in a mass production environment.” (Barman & Canizares, 2015, p. 65)

Da Silveira et al. (2001) highlight the process aspect in their definition regarding mass customisation:

“Mass customization relates to the ability to provide customized products or services through flexible processes in high volumes and at reasonably low costs.” (Da Silveira et al., 2001, p. 1).

Customisation of products and services can be implemented in different ways based on these different approaches. Gilmore and Pine (1997) present the four basic approaches to customisation including collaborative customisation, adaptive customisation, cosmetic customisation and transparent customisation. Lampel and Mintzberg (1996) have studied the
relationship between customisation and standardisation and identified continuum strategies regarding customisation and standardisation consisting of pure standardisation, segmented standardisation, customised standardisation, tailored customisation and pure customisation. Tseng and Piller (2003) identified four levels, in which mass customisation is performed. Figure 1 illustrates these four levels, which consists of three customer-centric viewpoints (rectangular areas) and internal perspective (triangle-shaped area) focusing on a system of a mass-customising company.

Figure 1. The four levels of mass customisation (Tseng and Piller, 2003).

Mass customisation can also be approached from a different angle. The Deloitte consumer review (Deloitte, 2015) identifies three distinct degrees of product and service personalisation. Table 1 summarises these degrees with brief descriptions and examples.

Table 1. Degrees of product and service personalisation (Adapted from Deloitte, 2015).

<table>
<thead>
<tr>
<th>Degree of personalisation</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass personalisation</td>
<td>Mass-produced products can be modified by the business based on the existing data about the individual.</td>
<td>Amazon’s personalised recommendations based on purchase history.</td>
</tr>
<tr>
<td>Mass customisation</td>
<td>Mass-produced products with limited options to customise the product or service by the consumer.</td>
<td>Dell’s options to customise computers to be purchased by the consumer.</td>
</tr>
<tr>
<td>Bespoke</td>
<td>The consumer is closely involved from beginning to end of the process to create an individual product or service.</td>
<td>‘A Suit that Fits’, a suit tailoring business, provides personal tailoring services.</td>
</tr>
</tbody>
</table>

Products are customised in various ways and there is not a defined set of attributes to be used commonly in customisation. Requirements for implementation of mass customisation are strongly related to a specific industry and product offering and available number of customisable features can differ clearly between different companies and products. Accordingly, McCarthy et al. (2003) have defined from the customer perspective ten
customisable product attributes, which are dimensional fit/size, hardware function, software function, property of the whole product, grade, quality, aesthetics and style, personalisation, literature and packaging. This list of customisable attributes reflects the multifaceted nature of the mass customisation concept.

Numerous actors in the clothing and textile industry have expressed interest towards customisation and different types of customisation are utilised in different areas of textile and clothing production. According to a McKinsey apparel CPO survey (McKinsey & Company, 2017), 29% of respondents view that mass customisation will have a high impact and 33% of respondents view that it will have a medium impact on the apparel sector over the next five years.

2.1.2 Applicability in a textile and clothing industry

There are existing models for mass customisation in the apparel and textile industry (Nayak et al., 2015, Watcharapanyawong et al., 2011, Dong et al., 2012, Lee & Chen, 1999). There are plenty of future scenarios on how mass production can be realised in the apparel industry. Table 2 available online in the Cornell University web site (https://courses.cit.cornell.edu/cuttingedge/production/04_production.htm) and adapted from Duray et al. (2000) summarises the apparel customisation model from three perspectives: point of customer involvement, apparel mass customisation options and enabling technologies.

Table 2. Apparel mass customisation model (Available from Cornell University web page and adapted from Duray et al., 2000).

<table>
<thead>
<tr>
<th>Point of customer involvement</th>
<th>Apparel mass customisation options</th>
<th>Enabling technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns</td>
<td>Custom fit or design</td>
<td>Body scanner, digitiser and CAD</td>
</tr>
<tr>
<td>Design</td>
<td>Component choice: size, style, fabric</td>
<td>CAD and web-based product configurators</td>
</tr>
<tr>
<td>Production planning</td>
<td>Data forecast</td>
<td>EDI &amp; production planning software</td>
</tr>
<tr>
<td>Assembly</td>
<td>Small-lot repeats</td>
<td>Electronically controlled eqpt robotics &amp; UPS</td>
</tr>
<tr>
<td>Distribution</td>
<td>Point-of-sale data</td>
<td>EDI &amp; supply chain management software</td>
</tr>
<tr>
<td>Post purchase</td>
<td>Customer adjustments</td>
<td>Electronic settings for smart clothing, gel gloves that mould hands</td>
</tr>
</tbody>
</table>

Communication with customers through design and development process and the utilisation of modules/segment in a production are integral parts of apparel mass customisation (Yang et al., 2015). In mass customisation the customer’s role is highlighted already at the beginning of the value chain. Nowadays, a wide range of different technologies are available to be used in apparel mass customisation production. Enabling technologies and tools include, e.g., Internet and web, CAD/CAM systems, 3D body scanner, flexible manufacturing system, data analysis system, inventory and distribution management system and digital printing (Nayak et al., 2015). These technologies support mass customisation in different phases of the production. It is noteworthy that the maturity level of these technologies is varying and many of these
technologies require relatively high investments from apparel companies. Table 3 illustrates an example scenario regarding mass customisation of the future based on body scanning and flexible production (Nayak et al., 2015).

Table 3. Comparison of traditional mass production and custom production of the future scenario. Adapted from Nayak et al., 2015.

<table>
<thead>
<tr>
<th>Traditional model of mass production (today)</th>
<th>Custom production future scenario (tomorrow)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Designer's concept:</strong> The clothes you buy off the rack begin as a designer's concept; each new style begins as a sketch</td>
<td><strong>Your Concept:</strong> You can have the garment you imagine by being involved in the design process</td>
</tr>
<tr>
<td><strong>Fit Model:</strong> A pattern is developed and fitted to a fit model. The fit model is chosen because its body size and shape represents the designer's vision of the ideal customer for this style. The pattern is perfected on the fit model and then proportionally increased and decreased (i.e. graded) to make a size range of patterns</td>
<td><strong>Individual Fit:</strong> You are scanned in a 3D body scanner to collect quick, accurate body measurements which will be used to achieve individualised fit</td>
</tr>
<tr>
<td><strong>Mass Production:</strong> Garments of all sizes are sewn at the same time using mass production methods. The mass production process provides a volume–cost advantage</td>
<td><strong>Flexible Production:</strong> Your individualised garment is made using sophisticated machines and flexible processes that accommodate one-of-a-kind production. Increases in production costs are offset by reduced inventory</td>
</tr>
<tr>
<td><strong>Inventory Shipped to Store:</strong> Garments are shipped to the store to be sold in size sets of identically styled and proportioned garments</td>
<td><strong>Delivery to Your Home:</strong> Your custom garment is delivered to your home</td>
</tr>
<tr>
<td><strong>Misfit:</strong> The dress designed for the fit model cannot fit all bodies well. In this example, the wrinkles indicate misfitting at the armhole, bust and high hip area</td>
<td><strong>Custom Fit:</strong> Your uniquely styled garment fits you well in size and proportions</td>
</tr>
</tbody>
</table>

Below are some examples of customisation services that provide an online configuration/design tool for customers for customising products. These services cover a wide range of different types of customisation options and product offering from garments to furnishing fabrics.

- Apliq: [https://www.apliiq.com/designyourown/](https://www.apliiq.com/designyourown/)
- Lands’ End: [www.landsend.com](http://www.landsend.com)
- iTailor: [https://www.itailor.com/](https://www.itailor.com/)
- mi Adidas: [https://www.adidas.com/us/customizable](https://www.adidas.com/us/customizable)
- Unmade: [https://www.unmade.com/](https://www.unmade.com/)
- Zazzle: [https://www.zazzle.com/custom/clothing](https://www.zazzle.com/custom/clothing)
- Black Lapel: [https://blacklapel.com/](https://blacklapel.com/)
- Spoonflower: [https://www.spoonflower.com/](https://www.spoonflower.com/)
- My Fabric Designs: [https://www.myfabricdesigns.com/](https://www.myfabricdesigns.com/)
- Fame and Partners: [https://www.fameandpartners.com/](https://www.fameandpartners.com/)
- Post-Couture Collective: http://www.postcouture.cc/

Overall, mass customisation can be implemented in different combinations of customisation and mass production and by identifying appropriate levels of modularity (pre-assembled pieces) and variability (customer-specified differences) related requirements for production (Yang et al., 2015). Typically, when a modularity is high, variety for fulfilling the customer's needs is low and vice versa. Mass customisation can also be divided based on the utilisation of manual operations vs. automation and explored through the concepts of traditional mass customisation and innovative mass customisation (Yeung et al., 2010). In addition, for some companies, mass customisation can be a starting point for the whole business (e.g. iTailor) or it can be one part of the business activities and service offering (e.g. Lands' End).

2.1.3 Barriers and opportunities

There is a wide range of benefits and opportunities identified in the adoption of customisation in production. An obvious benefit for the customer is that (s)he can get products that meet her/her needs, desires and preferences. In addition to benefits gained by customers, mass customisation provides potential benefits for companies offering customisation services. According to Yang et al. (2015), benefits gained from apparel mass customisation can include:
- Achieve a certain level of economies of scale and economies of scope
- Innovative design and consumer-centric fit
- Higher individual customer satisfaction
- Low return rate
- No overstock

Table 4 by Nayak et al. (2015) illustrates differences between mass production and mass customised production. This comparison of production models makes some potential benefits of mass customisation visible.

Table 4. Comparison between mass production and mass-customised production. Adapted from Nayak et al., 2015.

<table>
<thead>
<tr>
<th>The old methods of mass production</th>
<th>The new methods of mass customisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost, consistent quality and standardised product</td>
<td>Affordable cost, high quality and customised product</td>
</tr>
<tr>
<td>Homogeneous market</td>
<td>Heterogeneous and segmented market</td>
</tr>
<tr>
<td>Stable demand</td>
<td>Demand fragmentation</td>
</tr>
<tr>
<td>Long product development cycle and life cycle</td>
<td>Short product development cycle and life cycle</td>
</tr>
<tr>
<td>Large lot sizes</td>
<td>Lot size of even one</td>
</tr>
<tr>
<td>Inflexible production</td>
<td>Flexible production</td>
</tr>
<tr>
<td>High overhead</td>
<td>Low overhead</td>
</tr>
<tr>
<td>High inventories: build to plan</td>
<td>Low inventories: make to order</td>
</tr>
<tr>
<td>Separation of thinking and doing</td>
<td>Integration of thinking and doing</td>
</tr>
<tr>
<td>Lack of investment in worker skills</td>
<td>Sense of community</td>
</tr>
<tr>
<td>Poor management–employee relations</td>
<td>Better relationship</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Separation of innovation and production</td>
<td>Integration of innovation and production</td>
</tr>
<tr>
<td>Poor supplier relations</td>
<td>Supplier interdependence</td>
</tr>
<tr>
<td>Disregard for many customer needs and wants</td>
<td>Quick response to changing customer desires</td>
</tr>
<tr>
<td>Short-term managerial decisions</td>
<td>Sound long- and short-term decisions by managers and workers</td>
</tr>
</tbody>
</table>

Besides opportunities, there are also barriers to overcome before mass customisation can be widely adopted in the apparel and textile industry. Yeung et al. (2010) discuss mass customisation-related challenges in two categories: 1) external complexity meaning, e.g. customer confusion in front of a wide range of available product varieties, and 2) internal complexity including investments in training salespeople, defining complex product variants, and change of existing business models. Some technologies need to be developed further so that they can fully support the requirements of mass customisation in the apparel sector. For example, there have been challenges integrating 3D body scanning solutions into apparel production (Nayak, 2015). Despite some identified challenges, interest towards 3D scanning has been increasing, numerous organisations have invested in developing technologies in this area recently (see e.g. http://www.3dbody.tech/) and new, more advanced 3D body scanning applications have been launched globally.

According to the blog text of Frank Piller (2012), two specific reasons for failures of mass customisation companies are related to inadequacies regarding offered toolkits and identifying customer needs and creating flexible fulfilment processes. Also, according to Barman and Canizares (2015), the process of determining customers’ needs is one of the biggest challenges in implementing mass customisation.

There are also possible challenges in combining inventory management with mass customisation. Due to the nature of mass customisation, it can be troublesome as there is uncertainty in demand and supply (Yeung et al., 2010). A recent blog post by Ankit Upadhyay (2017) highlights cost, production speed, brand identity loss, and return policies as the most challenging issues for the companies implementing mass customisation in the fashion industry.

2.1.4 Summary

Clothing is a natural form of self-expression for people. People are focusing on individual clothing now more than ever before and this requires actions from the companies in the apparel and textile industry. Nowadays, an increasing number of companies in the apparel sector are implementing mass customisation to better fulfil the needs and preferences of their customers. Successful adoption of mass customisation requires apparel companies to rethink their approaches to their products and production processes. Mass customisation can be implemented in different levels and companies must explore, e.g. modularity and variety of their products from new perspectives.

New technologies play a crucial role in the implementation of mass customisation. Technologies, like AR, 3D scanning, and e-wearables, are enhancing the implementation and applications of mass customisation. It can be expected that utilisation of technologies will change how people shop for clothes online and at retail stores. In addition, advancements in flexible manufacturing systems and computer-aided-manufacturing will enable companies to implement their mass customisation more efficiently in the future.

References:


2.2 Digital fitting solutions

2.2.1 Overview

Digital fitting solutions can relate, for instance, to Augmented Reality interior design, but this section outlines digital fitting only for the clothing industry. Thus, the digital fitting here is limited to a virtual fitting room, a.k.a. a virtual dressing room. The virtual dressing room is an online equivalent version of a physical changing room located in a shop. The virtual fitting room enables users to try on apparel virtually instead of physically doing so.

The concept of a virtual dressing room has a quite long history. For example, in May 1995, Cyberware announced the introduction of the first 3D scanners to capture the shape and colour of the entire human body in one pass (Cyberware, 1995). It was mainly applied to measuring individuals in the US Air Force for perfect fit uniforms (Clothing Appearance and Fit, 2004). Figure 2 presents an example of the virtual dressing room.

![Figure 2. Example of a virtual dressing room.](image)

Alongside technology advancements, the virtual dressing rooms started to emerge around 2005 and during the last decade several prominent retailers began using virtual dressing rooms in their online stores, such as Gap (Gap, 2017) and Ralph Lauren (Ralph Lauren, 2016). As a domestic example, Stockmann is offering a digital fitting service developed by their own ICT department (Stockmann, 2015).
2.2.2 Applicability in a textile and clothing industry

There are several technological approaches for digital fitting solutions. Perhaps the simplest possible solution for a virtual fitting room is to use a measuring tape and letting the consumer enter measurements – such as height and waist size – into an online shopping service viewed, e.g. on a laptop computer. For example, U.S. Polo is using this kind of approach and according to their technology provider, this technology increased consumers' shopping cart size by 52 percent and dropped item returns by 64 percent (US Polo, 2013).

Italian start-up company, XYZE, is trying to enhance that kind of manual measurement by developing a wireless smart digital measuring tape coupled with a mobile phone application which furthermore is connected to various clothing brands and stores (XYze, 2015).

Those kinds of measurement methods are simple and very cost effective for retailers but can result in a bad or unsatisfactory user experience. If the service uses a virtual 3D mannequin as a showcase, the angle of view can be adjusted and the fitting is perfect, but the user experience can be clinical or appear like a digital character in a computer game. Thus, the person is easily disconnected from the virtual fitting experience. Even if the users could upload their own 2D picture, or selfie, into an online shopping service, the viewing angle of the superimposed apparel can be fixed or very limited and virtual fitting would not fit the actual user's body shape. Strictly not speaking about clothing, but an example of fashion instead; Ray-Ban has overcome many of these possible pitfalls in their online shopping place for sunglasses. The user is able to create a virtual model of the user’s own head by recording a few seconds video using a webcam, laptop camera, smartphone, etc., while turning their head slowly from left to right. The user is instructed to place their head inside of a visualised oval in a camera image and thus the fitting will be correct. After recording, i.e. creating the virtual 3D model on Ray-Ban's web service, the user can view different sunglasses perceived at different viewing angles and is able to verify how the glasses would really look on that specific person (Ray-Ban).

More sophisticated digital fitting solutions include measuring unit calibrated 3D body scanning, creating of a virtual look-alike 3D model of a person (to be used in a Virtual Reality environment) or using a real-world video of a person (to be used in Augmented Reality environment).

There are several technologies enabling how 3D scanning can be performed. For instance, using structured light where a pre-defined light pattern is projected on a subject (on a person) and analysing pattern deformations from the camera image. By calculating the transformation between the known light pattern and deformed light pattern, a depth map is revealed and thus the 3D information is available from the current viewing angle. Kinect, for example, uses a structured infrared light pattern for 3D modelling of user movements.

Google recently developed and introduced a 3D scanning platform for Android, namely the Tango platform, formerly known as Project Tango. The platform enables devices to perceive the real world in 3D, including calibrated physical space measurements. This can enable the virtual dressing rooms of everyday consumer devices. The virtual dressing room by Gap is powered by the Tango platform (Gap, 2017). As of today, there are two normal-priced devices on the market with the Tango platform implemented; Asus ZenFone AR and Lenovo Phab 2 Pro. Similar 3D scanning functionality can be added to a mobile device by using a separate add-on device, such as the 3D System, iSense, for iPad Air 2 (see Figure 3).
Advanced 3D body scanners can be constructed, for instance, by utilising multiple-camera setup, laser, THz radio waves, etc. One benefit of using high-tech scanning methods is that 3D scanning can be performed in one pass instead of forcing end users to be scanned from several different angles multiple times. More-detailed technical aspects of 3D scanning and similar technologies are out of the scope of this report.

The user experience can be further improved by utilising immersive display technologies. Microsoft recently published HoloLens, which is more or less providing a new step in head-mounted displays and especially as a display device for Augmented Reality applications. The clothing industry and fashion business utilised its opportunities immediately. The following is just a short collection of news in year 2017 about HoloLens applications in the clothing industry and.

- **A Glance into the Future of Footwear – HoloLens 3D Configurator for ROBOshoe, project by ELSE Corp, ATOM Lab**
- **Holographic Fitting Rooms Are Here with HoloLens & Pictofit**
- **Hololens for fashion designers**
  [https://www.youtube.com/watch?v=AzRTLOIQehY](https://www.youtube.com/watch?v=AzRTLOIQehY)
- **Virtual Fitting Rooms with The HoloLens**
- **HoloLens Project Makes Shopping for Clothes Easier**
  [https://www.psfk.com/2017/03/hololens-project-makes-shopping-for-clothes-easier.html](https://www.psfk.com/2017/03/hololens-project-makes-shopping-for-clothes-easier.html)
- **Here’s what the Microsoft HoloLens can do for designers and artists**
- **High fashion start-up use Kinect and HoloLens for futuristic retail experience**
- **Holo Fashion**

These examples indicate that digital fitting solutions can bring benefits and added value to value chain in clothing industry. The Gartner Hype Cycle for Emerging Technologies ([Gartner](https://www.gartner.com/en)).
2017) shows that both Augmented Reality and Virtual Reality have now passed the ‘Peak of Inflated Expectations’. VR is now on the ‘Slope of Enlightenment’ and is expected to reach the ‘Plateau of Productivity’ in 2 to 5 years. AR is still trying to catch up and it is expected to reach the plateau in 5 to 10 years from now. These predictions do not mean the development could not be realised at a faster pace.

2.2.3 Barriers and opportunities

The digital fitting solutions still face barriers. Many of these relate to people’s behaviour and attitudes, but not so much attitudes toward technologies any more, although they still exist to some extent. A user acceptance test for virtual fitting rooms clearly indicated security concerns, privacy concerns, performance expectancy and other barriers, too (User acceptance test, 2011). The issue remains today and might even have worsened due to recent news of many kinds of user data abuses. In order for digital fitting solution to work in practise, a consumer’s size measurement data or even 3D body scanned data is stored at least for a while – if not permanently – into a service provider’s or retailer’s data system. As stated by VP of global strategy and business development at Gap, “I’m not sure all customers want that.” (RetailWire, 2017).

Patents can also be considered as a barrier for digital fitting solutions, depending on the viewpoint on the market. Several existing patents might prohibit development of virtual dressing rooms without additional licensing fees. Google Patents with search terms ‘virtual+dressing+room’ results in approximately 1600 patents (Google Patents, 2017). Major players include, e.g. eBay and Microsoft.

The physical warehouse in between a clothing factory and a fashion shop might disappear completely from the delivery chain and thus gain large savings in logistics and investments. This can also enable global item shipping without any local warehouses and/or actual already manufactured unwanted items.

2.2.4 Summary

The digital fitting solutions can help ordinary consumers find a better fit for apparel according to their actual body measurements, body shape and style. Sizing technology has been trying to solve the fitting problem for decades so far. One of the biggest benefits of using digital fitting solutions would be the decrease in online shopping item returns. It relates not only to sales, but the whole chain of logistics, warehouse volumes, etc. Gartner’s hype curve still assumes years of development time before VR/AR is considered a mature technology. However, many solutions exist already despite predictions, also in Finland.

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### 2.3 Data in fashion

This section gives an overview of utilisation of customer data from multiple perspectives.

#### 2.3.1 Overview

Technology and digitalisation has enriched the overall customer experience in many industrial domains. Thus, it is natural that today’s leading fashion houses are looking at several ways to utilise emerging analytical technologies in fashion retail today (Agarwal). Julien Belisle from VisualNext say that analytics have become the foundation for high-performance businesses. Data is everywhere and the amount of data is continuously growing. Belisle also sees that Business Intelligence has changed a lot in the last decade and high-end computing has made data analysis more accessible. Today, Business Intelligence is an umbrella term that refers to a variety of software applications used to analyse an organisation’s raw data (Belisle, 2016).

In fashion, big data consists of companies’ internal data and customer behaviour data coming from various sources. Consumers have changed from passive players to active by contributing content and actively taking part in social media. This data includes videos, images, text and “likings” in social media and forms an unstructured data set coming from the consumers. The customer behaviour and different phenomena in social media actually shape fashion and represents a big data source for predicting the future more accurately.

During the fifth Fashion Tech Week in Paris, a Fashion and Technology panel discussion pointed out that the analysis of customer data lends itself to limitless applications along the entire fashion value chain. Professionals see that its impact is immense, whether in terms of customer satisfaction, competitiveness, revenues or waste limitation. During discussions, they remarked that algorithms and big data analysis can reduce left-overs by anticipating demand several weeks in advance in order to optimise the price and replenishment. Moreover, fashion companies who exploit data to inform their decisions become more efficient. They are better
armed to protect their margins, but can also sell for less, and potentially reach a larger number of consumers (Hanson 2017).

2.3.2 Applicability in a textile and clothing industry

According to a blog text on Manipal ProLearn’s web site (Education services for IT professionals), Data Science is changing the fashion industry by collecting and processing data and giving actionable insights on it. A lot of data can be mined and analysed including engagement on social media posts, trends on Instagram, what celebrities are wearing, what people are buying and much more. Data can be mined with advanced models and its output is converted into a form that even a layman can easily understand (Hanson 2017).

Data Science can also help the fashion industry with various predictive algorithms that help fashion companies make wiser business decisions. For example, fashion trends can be forecasted to tell a retailer whether, e.g. the latest fashion trend will get a good response or not (Hanson 2017). Vaishali Sharma from WebProfits thinks that extremely large sets of data, which help professionals to reveal patterns, associations, and trends, play a crucial role in the fashion industry. According to her, fashion professionals can analyse structured or unstructured data, segregate it into groups or categories, and then form a definition about the current trends and patterns in the fashion sector. She believes big data could also help the fashion industry to come up with new ideas, emerging patterns, shapes and styles, which may take them to a more successful future in the fashion domain (Sharma 2017).

A fashion company such as Zara manufactures huge volumes of clothing for different demographics globally. When operating at such a huge scale, something as simple as size, body shape, colour preferences and quantity will vary greatly. Data Scientists gather purchase behaviour of consumers and split it into different categories such as age, gender, price range, popular colours or other parameters. This helps a company predict the quantity and type of clothing that will be sold next season. This model can save millions of dollars by reducing the number of overproduced products. It should be noted that just basic data analysis techniques for data could help an organisation make well-informed decisions.

Akita Gupta from BigData-MadeSimple.com brings up a couple of big fashion companies like Prada, Nordstorm, United Colors of Benetton, Bulgari, Puma and Diesel, which are extensively using analytics in their businesses. Although, the use of big data cannot ever completely redefine the fashion industry, as it is more related to art, innovation and creativity than science and numbers, but it definitely is revolutionizing the way industrialists and brands produce apparels and accessories. Data analytics helps marketing and advertising become effective and it also helps companies optimise their supply chains as they can now decide what to produce more of and what should be stocked in inventory, and at the same time what can be kept for made-to-order or just-in-time. Akita believes that intuition and innovation design this industry but big data is what gives it shape and direction (PromptCloud, 2017).

Currently there is a wide range of data-driven services that companies are providing for the fashion industry. The following text briefly describes some of these services.

EDITD promise to help fashion retailers to have the right product at the right price and the right time. EDITD’s solution aggregates fashion trend and sales information from a wide variety of sources around the globe – from retail sites, social media, designer runway reports, and blogs covering trends – and then makes it accessible in real time. They claim that they have the biggest apparel data warehouse in the world. It offers that data to customers along with real-time analytics and an assortment of other tools, powered by 120 servers and hundreds of terabytes of data. Based on the analysis, industrialists are able to understand what the customer wants so they can customise their products accordingly.
WSGN offers trend forecast and big-data offerings for fashion retailers. WGSN claims its dataset has more than a million products and 11 million SKUs each day from more than 10,000 global online brands and retailers. Instock, which is essentially WGSN’s retail analytics service, is intended to complement its widely used trend-forecasting service by adhering to the same product-categorisation taxonomy.

ITC Infotech’s SPA (Style Performance Analytics) combines ERP, PLM and BI to analyse past data based on popularity and help user predict consumer preferences. Clients at the intersection of fashion, business & technology use ITC Infotech’s Style Performance Analytics (SPA) solution to integrate the latest technologies across their value chain and create innovative, winning products.

Intelligence Node is helping retail companies to succeed by offering a team of professional and innovative retail data experts to meet their needs. Intelligence Node serve global retail companies with a large and clean retail product database. They claim to have created the largest global retail product index that tracks real-time price and catalogue movements for major retailers. They also say they get data points by mapping more than 1 billion unique products across over 130,000 brands for more than 1,400 categories every day. To deliver market insights and competitor intelligence, they process more than one petabyte of data per month. Over 100 global retailers and brands consume their insights to guide retail life-cycle decisions.

Euclid Analytics is a company, which uses location-based analytics to be used in apparel stores. Their system collects data of where consumers spend the most time, what they purchase, and like seeing, etc., obviously with their implicit consent. Euclid essentially uses wi-fi signals from smartphones to track and analyse everything from the number of people visited in the store, to the time they spend inside. All of these data can be used to better service the customer and generate valuable analysis about customer habits in the store.

Lectra’s key know-how is in implementing digital transformation change in the fashion industry. Their fashion and apparel solutions help companies enhance their value chain and develop better collections with expertise based on best-practice methods and technologies. Mastering the fashion lifecycle from design to production is critical to leveraging creativity, streamlining time to market and controlling costs. These are elements necessary to building a better product and being competitive.

2.3.3 Barriers and opportunities

Due to globalisation, there are many apparel industry challenges that fashion industry brands experience, which has forced them to adapt significantly over the past decade. Customers expect to see a wide variety of styles in stores that are cost effective and of high quality. This places immense pressure on brands and retailers to lower costs while shortening lead times. On the other hand, Rajnish Kumar says fashion brands face the challenges of integrating available information in decision making. Their existing processes are mostly manual and may offer only limited data to buyers. The following challenges are identified in many sources: (Kumar 2013), (Sen 2016), (SgT Group 2017), (Beswick 2016), (Favre 2013).

- Sustainability: Consumers are aware of how retailers and brands handle sustainability issues. It is an important value for consumers today.
- Consumer demands: Fashion retailers need to be very informed of consumers’ needs. Consumers are used to access products not only from brick and mortar stores but online retailers instantly. Consumers demand notifications about a sold-out product that becomes available, and they demand customisable and unique products. Fashion brands also find it tough to keep customers engaged.
- High competition: The cost of production is increasing globally and apparel brands are finding it harder to find profitable sources for production and simultaneously trying to meet their production and quality demands.
- Brand sensitivity: A number of variables can affect a brand’s quality or name. Quality of products, availability of goods in stores, and sustainability of manufacturing are important for brand maintenance.
- New technology: Digitalisation and new technology are complex to implement and exploit in the fashion industry, because the use of the technology requires cooperation of different players in the supply chain. There is also a growing need to teach managers to deal with these technologies to get the best available benefit out of it.
- Fast fashion: Consumers have become accustomed to seeing the same outfit their favourite celebrity wore on the red carpet in stores the following week at a much lower price.
- Fashion is dynamic: There is little insight into why customers preferred a particular design over the other and there is no guarantee that a high fashion design will be successful.
- Lack of valid data: Lack of market data makes it almost impossible to judge the success of a new inspiration. Without market data, designers have to rely on their own judgement in selecting the right inspiration.
- Choosing the right size: A problem with online store shopping is getting the right sizes without physically trying on a piece of clothing.

To overcome these challenges, Kumar introduce some technical solutions for the fashion industry. Kumar mention that Robust Product Lifecycle Management (PLM) systems have been gaining popularity across fashion brands. These platforms can define design lifecycle-related parameters holding product attribute information to help monitor new designs while getting all development information on a single platform. Additionally, analytics through business intelligence (BI) tools has been regarded as one of the defining technologies for this decade, say Kumar. Representation of the PLM and ERP information on a BI tool through visual interfaces such as dashboards makes analysis easier and standardised across functions (Kumar 2013).

Cognitive computing could be used to get closer to what consumers might want. Cognitive computing is a set of programs, which can simulate and mimic the brain’s thought process function. This is resulting in plenty of new data for companies to analyse. With the help of analytics, they can derive business intelligence from it and collaborate their production and delivery accordingly. The major value proposition is getting pre-emptive information about what could be the most probable item for sale and when to sell it, which in turn could help manage costs in operations and logistics (Sen 2016).

One significant problem with online shopping is getting the right sizes without physically trying on a piece of clothing. This is because different fashion houses make clothing sizes differently, according to their own style guide. According to Wrik Sen, data analytics can be used for matching the consumer to the right fashion house from where they could purchase items, resulting in fewer returns of products sold (Sen 2016).

A practical challenge in companies can be a lack of data-oriented and experienced personnel, and consequently a company culture that is not supportive for constructing and implementing a data-driven business model (Brownlow et al., 2015). Some companies are already solving the challenges regarding generating a business value from data by hiring chief data officers that can push the data-driven approach forward in the company.

Utilisation of data has also numerous potential benefits for the fashion industry. According to Seema Agarwal, VP Product Management at Manthan, (Agarwal) and Julien Belisle (Belisle, 2016), there are many ways in which data science technology can benefit the fashion industry. The following text gives examples of target areas, which can benefit from advanced data-driven solutions.

**Digital marketing** (social media and online advertising on mobile devices) will continue to grow as integration of offline and online customer experience is on the rise, Agarwal predicts.
She says that this has increased consumer brands’ abilities to digitally influence customers and digitally empowered customers’ abilities to influence brand image and value (Agarwal).

**Personalised offers and tailored campaigns**

Combining massive amounts of available data with today’s technology advancements, fashion enterprises are utilising big data technologies to analyse huge amounts of customer data, understand patterns and subsequently personalise their offers to their customers. This could help them to be wiser in their decision-making and surpass the competition. Enabling strategic customer segmentation can drive a consistent marketing strategy across all concepts. According to Agarwal, a customer acquisition and tailored campaigns could increase customer engagement and loyalty. By understanding customer attitudes, their purchase behaviour and identifying fashion trends, companies are able to make smarter marketing decisions (Agarwal).

**Predicting future trends**

Fashion retailers can shorten seasonal cycles with the right real-time insights to meet changing customer preferences. By using data analytics, retailers can have more flexibility in their supply chain responsiveness.

Modern analytics solutions make it possible to enable greater precisions with in-season control, which are leading to derived insights and optimisation of essential things like product, promotion, pricing, placement, and people. Successful predictions with the help of data analytics can help neutralising surprises in customer demand and minimise losses (Agarwal).

In his blog, Julien Belisle predicts that 1.7 megabytes of new information will be collected every second for each individual on the planet by 2020. This is an enormous sum of data, which means that finding applicable insights will become increasingly difficult. Belisle’s opinion is that in order to become more accessible and user friendly, organisations must utilise machine learning and Artificial Intelligence to go beyond the classic analytics. They have to start predicting future trends and business opportunities with the help of new technology (Belisle 2016).

Data analytics and web crawling emerge as highly important concepts. Designers and clothing materials manufacturers can extract information from these social media channels, and thus get an idea of the real scenario. Data extraction and web crawling is extremely important. Data analytics can gain clear insights into current trends in the following ways:

- **Individual product details**: Companies embracing data extraction have the opportunity to gain targeted information on individual products. That will help them develop ideas about consumer preferences and consumption patterns.
- **Predicting consumer choices**: Web crawling will help companies identify customers’ browsing patterns. It helps in comprehending their choices and increases opportunities to forecast customer demands.
- **Sentiment Analysis**: Intuition and emotions regulate buyers’ decisions and choices. To gain more understanding of the buying decision, it is imperative to understand buyer sentiments. Data analytics will help to reveal the nuances of these aspects (PromptCloud 2017).

**IoT fitness devices**

Health and wellness has become a trendy lifestyle for many individuals over the past few years. Wearable sensors can be embedded into clothing, sportswear, shoes, and trackers, resulting in a large amount of generated fitness data. Combining that fitness data with contextual data can result in highly useful and interesting insights for consumers, according to Agarwal. On the other hand, with the help of real-time analytics, retailers can create innovative engagement campaigns to further enhance the lifestyle choices that their consumers make, boosting loyalty as a result (Agarwal). Moreover, Belisle say that IoT not only has the potential to streamline this industry’s manufacturing process and enable real-time global forecasting, but smart textile will be a major disrupting factor in 2017. The author of the blog believes these new wearable
technologies will allow apparel companies to obtain accurate data on consumer behaviour, and so enabling accurate industry insights and product development (Belisle, 2016).

Data visualisation and story telling
Today advanced analytics will no longer be just for analysts or mathematicians. Currently, a majority of business and technology decision-makers still have difficulty getting answers from their dashboard metrics. Julien Belisle expects a solid upgrade of Business Intelligence (BI) software’s user interface here and now. While BI might be fuelling a fashion company with great new metrics and insights, the way to use this data to tell their story with a compelling narrative and visualisation is bound to provide context to fashion company teams and influence the decision-making process. Furthermore, it is very important to involve employees in data analytics, provide appropriate training, and support methodology definitions. Belisle highlights that without effective implementation and training, a fashion company’s business is likely investing in a BI solution that is due to fail because of poor adoption and disparity (Belisle 2016).

Business data availability
Seamless and transparent data integration in supply chain processes will be the driver behind a major manufacturing shift, says Belisle in his blog. Before, most business started collecting data with disconnected systems, branches, and channels. Today’s end-to-end software and new hardware integration allows multi-channel businesses to centralise data and offer total transparency. Belisle’s expectation is that Business Intelligence software will follow the mobility trend by making data compatible and accessible across different devices. With evolving cloud-based technologies combined with powerful smart devices the workforce will have access to emerging data preparation capabilities and to collaborative tools on the go (Belisle 2016).

Engaging and interacting with customers
International fashion house, Burberry, have used analytics to create a novel in-store customer experience that gave customers greater intimacy and interaction. They analysed data from customer purchases, surveys and social media and used the information to identify and greet their customers when they walked in the store. This helped Burberry to blend the in-store and online experience for their customers. Burberry used loyalty and reward programme information to offer personalised recommendations, both online and in store. When an identified customer enters a store, sales assistants use tablets to offer buying suggestions based on their customers’ purchase history as well as their social media activity (Marr 2017).

2.3.4 Summary
There is plenty of analytical data to be collected from various data sources in the fashion industry. The analysis of this very big data would help in deriving business intelligence, which in turn positively affects the way businesses in the fashion industry are run. Data analysis could lead them toward closer contact with what their customers want and what they are like with regard to their consumer behaviour (Sen 2016).

Data Science can also help the fashion industry with various predictive algorithms that help companies make wiser business decisions. For example, fashion trends can be forecasted to tell retailer whether or not, e.g., the latest fashion trend will get a good response. Or, e.g., cognitive computing could be used to get closer to what consumers might want. In addition, wi-fi signals from smartphones can be used to track consumers’ movements in a store. This data can be used to analyse everything, from the number of people who visit a store, to the time they spend inside. This data can be used to gain a better service level and generate valuable analysis about customer habits in the store.

Due to globalisation, there are many apparel industry challenges that fashion industry brands experience, which has forced them to adapt significantly over the past decade. The cost of production is increasing globally and apparel brands are finding it harder to find profitable sources for production and simultaneously trying to meet their production and quality demands.
In addition, customers are aware of sustainability issues and tend to be brand loyal. They also expect to see a wide variety of styles in stores that are cost effective and of high quality. This places immense pressure on brands and retailers to lower costs while shortening lead times. On the other hand, fashion brands face the challenges of integrating available information in decision-making. These challenges can be resolved, in whole or in part, with data science methods.

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2.4 Digital printing

This section outlines the current state of digital printing in the textile and clothing industries.

2.4.1 Overview

On a very general level, digital printing can be considered as a process of creating and using a digital file, which is sent to a printer (ToughtCo., 2017). Digital printing has a long history of printing text and graphics on paper and advanced printers have made it possible to print high-quality text and graphics already for many decades. Due to technological advancements, digital printing has also been increasingly used in the textile and clothing industry since the 1990s (Tyler, 2005). From the apparel product development perspective, digital printing can be defined as “Applying patterns of fabric using computer printer technology. Patterns created and stored in the computer can be selected, scaled and printed directly onto fabric.” (Keiser and Garner, 2008, p. 524). The need for the use of a printing plate is eliminated in digital printing, which make it a more flexible method compared many other printing methods. According to a forecast in Smithers Pira’s report, the digital textile printing global market is estimated to more than double in five years as it is estimated to increase from the current 1.17 billion euros (2016) to 2.42 billion euros by 2021 and the share of digital printing of all printed textiles is growing (Smithers Pira, 2017).

The textile and clothing industries have special requirements for digital printing methods. There are similarities between textile and paper printing, but digital textile printing has also some additional issues raised by the media to be printed, such as surface texture, end-use performance and colour physics (Tyler, 2005). Many of the challenges identified in digital textile printing have already been solved and digital printing is used quite commonly in particular areas of the textile and clothing industry. Even tough, digital textile printing has become clearly more common recently, it has only 3,5% share of all printing technologies used in a textile printing market according to Textile Outlook International (2016).

2.4.2 Applicability in a textile and clothing industry

Digital textile printing as a developing technique has become more common in the apparel industry during recent years. Digital printing can be used for different targets of use in product development. For example, in the development of yarn-dyed fabrics, instead of using physical yarn and fabric development processes, digital printing techniques can be used for printing multiple fabric effects for white fabric and used as a starting point for the physical sample development process (Rayak & Padhye, 2015).

According to Tyler (2005), digitally printed textile applications can be categorised as follows (some examples in brackets). The most links below provide a partial view of the different companies’ offerings. Often, companies providing digital textile printing, such as Kornit Digital from Israel (https://www.kornit.com/applications/), have different types of digital printing services for multiple areas.

1. Carpets
• Digital carpet printing started with Milliken's Millitron system (http://millikeninnovation.com/) and Zimmer's Chromojet system (http://www.zimmer-kufstein.com/) in 1970s.

• Zimmer (Austria):

• Printing Carpets (Netherlands):
  i. http://printingcarpets.com/home/

2. Photoshoot bureaux and sampling

• During the 1990s many smaller companies started to provide services regarding digital printing for small quantities of textiles to enable photoshoots for catalogues and other marketing activities.

• Digital Fabrics (Australia)

3. Flags and banners

• Printscorpio (Finland):

• Custom Flag Company (US)

4. Customised products: ties, scarves, etc.

• B&B Foulards (Italy)
  i. https://www.italianmoda.com/storefronts/bbfoulards/index.cfm

• Anne Touraine USA (USA)
  i. https://www.custom-scarves-and-ties.com/

• The Silk Bureau Limited
  i. https://www.silkbureau.co.uk/scarves-2/

5. Mass customisation and interior textiles/apparel

• Digital printing is one enabler of mass customisation among other technologies.
  i. See for example Nayak et al. (2015).

• Kornit Digital (US)

In addition to the application areas above, Tyler (2005) highlights the potential of high-productivity machines to digitally print solid colours and creation of short-run business models that require processing small batches in a cost-effective way.

A wide range of disciplines and competences are needed in the digital textile printing ecosystem. According to Burgess et al. (2004) key stakeholders in textile printing consist of printing companies/commission printers, designers/garment makers, equipment manufacturers/suppliers, ink manufacturers/suppliers, software manufacturers/suppliers,
material manufacturers suppliers, design schools and retailers/wholesalers. Ujiie (2006) identifies the following key elements and related competencies for producing digital textile printing: print head design and manufacturing, material handling engineering, ink chemistry, textile manufacturing and pre-treatment, post-print finishing, design, raster image processing (RIP) and colour management software. It can be expected that technical competencies in this area are needed increasingly as applications of digital inkjet technology are used for creating smart textiles in the future (Castano and Flatau, 2014).

2.4.3 Barriers and opportunities

Digital printing of textiles offers a wide range of new possibilities for the business actors operating in the textile and clothing industry. Digital printing has a potential to accelerate product development of textiles and clothes. For example, expensive physical fabric sampling process can be accelerated with digital printing methods (Nayak and Padhye, 2015). The following Figure 4 from Gupta (2001) gives an overview of the differences between conventional (left) and digital printing (right) in the context of design sampling.

![Figure 4. Differences in conventional and digital printing processes (source: Gupta, 2001).](image)

Generally acknowledged benefits of digital textile printing are its ability to print on demand, print short-runs and use thousands of colours (Thompson and Sanders, 2016). Digital printing is also more environment friendly than conventional methods (Gupta, 2001) as significantly less water, dyes and chemicals are needed in the production process. Digital printing is also one of the technologies that contributes to the mass customisation of textiles and garments (Nayak, 2015). It supports print of custom-made designs in both fabrics and garments (Gupta, 2001). Table 5 summarises advantages of digital printing (Asif, 2017).
Table 5. Advantages of digital printing (Asif, 2017).

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Description</th>
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| Quality                                       | - Flawless images.  
- Use of entire length of a printable item.                                                                                           |
| Speed                                         | - No need for time-consuming preparation activities.                                                                                        |
| Short-run printing advantage                  | - Efficient production of design with low run lengths.                                                                                      |
| Lower water and power consumption             | - Many resource-intensive actions are not necessary.  
- Demand for using water substantially decreased.  
- Use of digital inks more eco-friendly.                                                        |
| Less chemical waste                           | - Ink usage significantly lower than in a traditional printing.                                                                                |
| Large repeat sizes                            | - Ability to print easier large designs on fabric (e.g. sheets and blankets).                                                               |
| Reduces production space requirements          | - No need for storing customer screens for future use.                                                                                      |
| Less printed inventory needed                 | - Lower need for pre-printed inventory of fabric.                                                                                           |
| Sampling and production done on same printer  | - Samples (strike-offs) will exactly match with a final printed product material.                                                             |
| Print flexibility                              | - Printing houses using both screen and digital printing technologies can first test the market with small quantities of digitally printed products and later print large volumes of products using rotary screen technology. |
| Variety of creative design choices for printing| - Extended possibilities for fashion and interior designers through printing photographic/continuous tone images.                               |
| Low capital investment                         | - Digital printing shop is able to start with a relatively small investment and scale-up when business grows.                               |

Digital textile printing has still some issues that have hindered a wider adoption of this technology in the textile and clothing industry. Development has been done and developers in different areas have made advancements for tackling digital print-related challenges, such as print cost and print speed (Carden, 2015; Ujie, 2006). According to Asif (2017), the following specific issues limit the use of digital printing:

- Large particle size in inkjet printing machines impedes printing of metallic colours,
- Large volumes are expensive to print due to slower printing speed compared to conventional techniques, and
- Digital inks tolerate direct sunlight worse than offset inks.

2.4.4 Summary

The share of digital textile printing has increased in the textile and clothing industry compared to traditional methods, such as screen-printing, and it has been estimated that growth will continue in the future (Smithers Pira, 2017). During recent years, digital printing has been developing constantly while analogue textile printing has remained stagnant.

Currently, there is a wide range of companies that offer digital textile printing services for the textile and clothing industry. There are also service providers in Finland, which have a good capacity for digital printing services. Even though the share of digital printing is currently relatively small, it can be seen that digital printing, as a more environment-friendly and flexible method, will gradually take a bigger share among printing technologies. It can be expected
that in the future, as digital print technologies offer larger cost-effective print runs, it will be used widely in the textile and clothing industry.

**References:**


### 2.5 3D printing

This section outlines the current state of 3D printing in the textile and clothing industry.

#### 2.5.1 Overview

It has been estimated that 3D printing technologies, also called additive manufacturing, will transform every industry and disrupt manufacturing in the future (Petrick and Simpson, 2013). 3D printing means a process of creating three-dimensional physical objects from a digital file. In practice, in a printing process different levels of material are added layer by layer to create solid objects (see e.g. https://3dprinting.com/what-is-3d-printing/).

According to market research of MarketsandMarkets (2017), the 3D printing market will be worth 32.78 billion USD by 2023. North America, Europe and Asia have been in the vanguard of the 3D printing development. Globally there is a wide range of companies that provide 3D printing-related solutions, materials and services for different targets of use. According to the study of Sculpteo (2017) most of the 3D printing-related work done is in the early phases of
product development including prototyping and proof-of-concept and the top priority related to
3D printing is accelerating product development.

3D printing has attracted much attention in research and industry and this emerging market
has segmented across different domains. A report by the European Commission (2016)
identifies the following areas as the most relevant sectors, which are (or will be) impacted by
3D printing: aerospace, automotive, healthcare, machines & tooling, electronics and electronic
devices, consumer life style & fashion (including textiles and creative industries), oil & gas,
energy, construction, military, transportation (marine & special vehicles) and food.

The textile and clothing industry, as one of sectors utilising 3D printing technologies, has its
own specific requirements for a large-scale adoption of 3D printing technologies. In addition to
opportunities regarding production of traditional textiles and garments, 3D printing provides
new possibilities for manufacturing 3D-printed wearables including smart features in the
products. Gartner’s 3D printing hype cycle presents the maturity and adoption of 3D printing
industry-related trends. According to Gartner’s 3D printing hype cycle, 3D-printed wearables
are in the ‘on the rise’ phase of the cycle and it takes 5 to 10 years to mainstream adoption
(see https://www.gartner.com/doc/3759564/hype-cycle-d-printing-).

2.5.2 Applicability in a textile and clothing industry

There has been interest in applying 3D printing in the textile and clothing industry and
designers have especially used 3D printing for consumer products, such as dresses, shoes
and accessories, which cannot be implemented without 3D printing technology. Some famous
designers, like Catherine Wales (http://catherinewales.eu/) and Iris Van Herpen
(http://www.irisvanherpen.com/) have started to utilise 3D printing technologies to create
personalised clothing. However, 3D printing is not yet widely utilised in large-scale mass
production of garments. Although the 3D printing is not yet widely used in mass production,
there have been some initiatives that aim at achieving benefits from 3D printing in that area,
for example, in the production of shoes (see e.g. Techcrunch, 2017).

3D printing of textiles can be distinguished for two categories:

1. 3D printing of textile structures.

2. Combination of textile material with 3D-printed items, which can be either directly
   printed on the textile or integrated with it by other techniques (e.g. agglutination)
   (European commission, 2016).

Currently, 3D printing is focusing on a wide range of different types of wearing-related items.
Wearing-related objects are often unique fashion creations, single parts of some garment or
different types of accessories. The following list gives examples of wearing products ranging
from fully 3D-printed articles of clothing to trimmings and 3D-printed parts that can be
integrated with clothes:

- Jacket:
  - Danit Peleg: https://danitpeleg.com/
- Shoes and insoles:
  - RESA: http://www.resawear.com/
  - Adidas: http://www.materialise.com/en/cases/adidas-futurecraft-ultimate-3d-
    printed-personalized-shoe
  - Winbo: https://list.winbo.top/3d-printing/26142-26048.html

Roadmap for boosting the international growth of Finnish clothing and textile industry: Part 1
• Accessories:
  o Bangles: https://www.etsy.com/market/3d_print_bangle
  o Tie: https://3dprint.com/137623/3d-printed-neckties-3dtie-com/
  o Snapback badges: http://www.modla.co.uk/
  o Beanie: https://www.etsy.com/listing/539104194/jughead-beanie-made-to-order-riverdale?ref=shop_home_feat_1

• Dresses:
  o A List of 10 Unique 3D-printed dresses: https://i.materialise.com/blog/3d-printed-fashion-dresses/
  o Flexible, adaptable, fashionable patterns by using plastic filament (Alejandra Mora-Sanchez): https://www.cosineadditive.com/blog/2017/6/17/maria-textile

• Misc.:
  o Behnaz Farahi; Interactive 3D-printed top: http://behnazfarahi.com/caress-of-the-gaze/
  o Continuum; N12 bikini (the world's first ready-to-wear, completely 3D-printed article of clothing): http://www.continuumfashion.com/N12.php

In addition to industrial or manufacturing 3D printing, 3D home printing on personal 3D printers by customers is the area that has raised growing interest during recent years. 3D home printing or home fabrication extends the role of 3D printing beyond manufacturing as it can be used for product distribution (see e.g. Rayna and Striukova, 2016). Nowadays, basic 3D printers for consumers are available at regular electronic stores. An alternative to using a personal 3D printer is to use a service which prints the object based on a customer's design and ships the 3D-printed product to the customer. Currently, there is a wide range of 3D printing service providers offering these services. In addition to some of the services listed above, for example Shapeways (https://www.shapeways.com/) offers custom 3D printing services with a possibility to print different types of jewellery and personally designed models.

One trend in the textile and clothing industry is 3D knitting by using “digital knitting machines”, which are also sometimes referred to as 3D printers for fashion, even though 3D knitting is very different from typical 3D printing. 3D knitting machines follow the same basic procedure familiar from 3D printing with plastics: you put in a raw material (yarn), design your item with a digital tool and a machine generates a physical item for you. However, they do not utilise the layering process in the same way, which is used typically in 3D printing, e.g. with a plastic material. In addition, instead of having an extruder head, which is used in actual 3D printing, they use needles and a needle carriage. For example, Kniterate is a company that is developing a knitting machine with software that makes it possible easily create knitwear based on custom digital designs (see: https://www.kniterate.com/). Kniterate is a commercial branch of OpenKnit, which is an open source-based project (http://openknit.org/). Also, the US-based company, Ministry of Supply, has launched a service which utilises a 3D knitting machine using whole garment knitting for creating seamless clothes (see: https://www.youtube.com/watch?v=9McxufEzic0). The 4 footwear company, J&S Enterprises, has also introduced customisable 3D-knitted shoes, which are seamless and manufactured as a single piece (http://www.jsshoe.com). Disney research has focused on creating a compiler, which can automatically turn assemblies of high-level shape primitives into low-level instructions for a 3D machine knitting (https://www.disneyresearch.com/publication/machine-knitting-compiler/).

The 3D printing process for different types of textiles and garments requires a wide range of tools and competences from different areas. Competences from areas of 3D printer
manufacturing, raw materials, software and process design are a precondition for 3D printing services. Figure 5 illustrates the value chain including the needed elements for 3D printing of textiles.

Figure 5. Value chain of 3D printing for textiles (source: European commission, 2016)

2.5.3 Barriers and opportunities

Currently, plastics are the most-used material in 3D printing and Fused Deposition Modelling (FDM) is the most common 3D printer type (Sculpteo, 2017). In general, 3D printing clothing from materials that are comfortable to wear and flexible enough is still challenging and there is a clear need for additional development for creating materials that are suitable for daily use (Yap and Yeong, 2014). Insufficient mechanical properties, especially low tensile strength, have been hindering the use of 3D printing in textile and clothing production (Sabantina et al., 2016). In addition, filaments used in 3D printing cannot be machine washed, ironed and pressed like traditional textiles, they cannot be sewn, and they also lack of absorbency (Valtas and Sun, 2016). Additional work is also needed in designs for gaining drapeable textiles. In addition to prototyping or large-scale production, 3D printing is often seen to be an enabler for printing of different types of objects at home (see e.g. Bloomberg.com, 2017). Limitations related to material properties also affect 3D home printing and the affordability of 3D printers targeted to consumer markets. 3D home printers can be rather basic compared to high-end industrial machines.

In general, creating a fabric 3D printer has proven difficult. For example, a company called Electroloom tried to create “the world’s first 3D fabric printer” that prints an entire seamless garment (https://www.kickstarter.com/projects/electroloom/electroloom-the-worlds-first-3d-fabric-printer/). Their initiative has declined because of a lack of investment (https://3dprint.com/145749/electroloom-out-of-business/)

As 3D printing was not originally invented directly for the apparel industry, software tools used to create digital garment designs can be time-consuming and tricky to use for designing garments, which is especially troublesome at the mass manufacturing level (Valtas and Sun, 2016). Design tools used for digital models of 3D printing should meet the requirements of garment design principles in order to avoid extra work with tools. This relates partially to a wider challenge related to a lack of in-line processes regarding 3D technology, which is highlighted especially in the mass production of clothes (European Commission, 2016).
Despite identified challenges in 3D printing, it can be expected that apparel product development process will be improved through the integration of 3D printing technologies and other new digital technologies in the future (Nayak and Padhye, 2015; European Commission, 2016). In 3D printing-based manufacturing, laying, cutting, assembling and sewing can be merged into a single step, in which a design file is created by printing (Valtas and Sun, 2016). 3D printing entails opportunities also for smart textiles (European Commission, 2016).

From a customer perspective, one essential advantage of 3D printing is a possibility to get customised products, which fit the customer specifically (Pratt et al., 2012; Perry, 2017, Reilly, 2014, 2017). 3D printing can also be considered as a sustainable production process as it is not dependent on a location in a same way as traditional garment manufacturing technologies, but it provides a possibility to take production closer to the market (Valtas and Sun, 2016). It also makes possible achieving a zero waste level in the manufacturing process by avoiding misuse of material (Valtas and Sun, 2016; Perry, 2017).

In addition to opportunities regarding prototyping, 3D printing has the potential to change the apparel industry, expanding it to the area of mass manufacturing. However, there are not yet examples of using it in large-scale mass manufacturing. 3D printing is also expected to provide new business opportunities and change business models in the textile and clothing industry. Especially, direct manufacturing and home fabrication are disruptive and they will increase value creation and value delivery, however, at the same time they make value capture more challenging (Rayna and Striukova, 2016).

2.5.4 Summary

The use of 3D printing technology is still in a quite early stage in the textile and clothing industry and manufacturing is mostly limited to specialised fashion products made with plastics, specialised accessories and parts of shoes. 3D-printed textiles are still more often used in fashion shows and different types of demonstrations than in everyday clothing.

As 3D printing has earlier focused on other areas of industry with different types of material requirements, a major challenge of applying 3D printing in the textile and clothing industry has been related to materials. Plastics, which are commonly used in 3D printing, do not have material properties that people are accustomed to in clothing, such as those of cotton or silk. Research of materials related to 3D printing is underway and it is expected that research will create innovations in this area in the future (Melnikova, 2014; Beecroft, 2016). Another challenge is that technology is not yet available for in-line processes, which is required especially for a mass production of clothes (European Commission, 2016). Currently, there are initiatives, for example in shoe manufacturing, that aim at higher-volume production by utilising 3D printing technologies.

It can be expected that 3D printing will shorten the garment production development cycle and reduce production costs in the future. 3D printing also supports custom made clothing businesses and enables fabrication of seamless, perfect fitting clothes. When printers and printable materials are developed further, home fabrication will provide wider opportunities for business actors to develop their business and end-customers will have better tools to create customised clothing.

Altogether, currently there are many interesting companies utilising 3D printing, including many promising elements that can expand the benefit of the textile and clothing industry in the future. Still, more research and development is needed from different areas for creating novel solutions for industry use, enabling wider adoption and identifying business opportunities for different types of actors in the textile and clothing industry.
References:


2.6 Sustainability

Morlet et. al (2017) introduces a vision for a new textile economy based on the principles of a circular economy. The report is comprehensive and this section highlights only some of the topics.

Nowadays, the clothing system puts pressure on resources, pollutes the environment, and creates negative societal impacts. For instance, it is estimated that only 13% of the material in the clothing industry is in some way recycled (mostly to low-value products such as insulation material or wiping cloths) (Morlet et al., 2017).

Morlet et al. (2017) introduces a vision for a new textiles economy aligned with the principles of a circular economy. In this vision clothes, textiles, and fibres are kept at their highest value during use and re-enter the economy afterwards, never ending up as waste. The vision relies on four ambitions that need to be tackled to overcome the challenges. These ambitions are:

1. Phase out substances of concern and microfibre release.
2. Transform the way clothes are designed, sold, and used to break free from their increasingly disposable nature.
3. Radically improve recycling by transforming clothing design, collection, and reprocessing.
4. Make effective use of resources and move to renewable inputs.

The report points out that transforming the textiles industry into a circular economy model requires system-level change. The role of digital technology in this change is that it is an enabler to support the transition to a circular economy. The report presents that a new textile economy may benefit from RFID, open data access / sharing, 3D bodyscanning, 3D printing, online platforms and blockchain technology.

Reference:

2.7 3D virtual sampling

This section outlines the use of 3D virtual sampling in the textile and apparel industry.

2.7.1 Overview

There is a long history in the use of computer-based graphic systems in engineering as the first systems were utilised already in 1960s especially in automotive and aerospace industries (Bordegoni & Rizzi, 2011). Since then, systems have gradually developed and nowadays virtual prototyping is widely used in product development in different sectors including, e.g. construction (Huang et al., 2007) and assembly design (Shyamsundar & Gadh, 2002). In addition, opportunities of 3D-based virtual prototyping techniques have been studied in the context of garment design (Hardaker & Fozzard, 1998; Chittaro & Corvaglia, 2003). Increased computer power, advanced graphic technologies and more user-friendly applications have enabled a wider use of 3D technologies in the apparel industry (Lectra white paper). Nowadays, there are numerous commercial SW-based 3D methods and tools to be used for 3D virtual sampling in the product development of garments. 3D design is targeted to be connected to different product development phases from design, pattern making, production and manufacturing. In addition to 3D visualisations, utilising 3D technology for virtual fitting, can be seen as an integral part of the sampling process. Some vendors have estimated that by using 3D design and prototyping it is possible to cut overall production time by 30–50 % (Texprocess, 2015; Gerber Technology, 2017).

2.7.2 Applicability in a textile and clothing industry

Virtual clothing technologies provide solutions for a wide range of areas that can benefit types of actors in the value chain. Figure 6 from the study of Magnenat-Thalmann (2010) illustrates the different actors that can benefit from different virtual clothing technologies, such as 3D garment modelling, simulation and visualisation.

*Figure 6. Actors that can benefit from virtual clothing technologies (source: Magnenat-Thalmann, 2010).*
Figure 7 from Papachristou & Bilalis (2016a) illustrates differences between the traditional sampling process and 3D virtual sampling process. An essential difference between the traditional and 3D-based sample making process is that it is possible to eliminate sending numerous physical product samples back and forth and proceed earlier into the actual production phase by utilising 3D digital prototyping techniques. In addition, the figure brings out the sustainability aspect by highlighting the importance of technologies that can enable 3D virtual fitting for identifying a target market’s requirements and decrease the amount of product returns to near zero.

3D vendors, 3D expert users in apparel companies and 3D academics can be seen as key stakeholders in the development of a 3D virtual prototyping area. Nowadays, developed 3D tools often promise that physical sample making can be bypassed by utilising 3D technologies integrated with pattern making and digital fitting solutions. Generally, 3D apparel applications promise improvements in the following areas:

- Integration with pattern production software enables turning 2D patterns into 3D apparel samples and changes done in 3D samples can be seen in 2D patterns easily in design.
- 3D avatar of fit model can be created based on a body scan for getting a sample that precisely matches body dimensions.
- Fabrics can be visualised to replicate actual fabrics (textures, pleats, etc.).
- Characteristics of the fabric (e.g. draping and movement of the garment) can be presented through the 3D animation.
- 3D-modelled apparel designs can also be used for sales and marketing purposes.
Well-known commercial 3D clothing systems follow the 2D-to-3D approach, in which a flat pattern is done at first and then this digital pattern is virtually added around a 3D human body (Mok et al., 2016). The following list presents a wide range of vendors and their software tools for a 3D virtual prototyping of garments. Typically, tools offer 2D pattern making and 3D visualisation capabilities. Tools often provide also a possibility for 3D design directly to a human model to simulate the characters of the apparel on the human body/avatar.

- Optitex, 3D product creation suite: http://optitex.com/solutions/odev/
- Tukatech, Tuka3D: https://www.tukatech.com/3D-fashion-design-software/TUKA3D
- Browzwear: https://browzwear.com/products/  
  - VSticher: https://browzwear.com/products/v-stitcher/  
  - Lotta: https://browzwear.com/products/lotta/ (Integrated workflow with VSticher)  
  - SmartDesign: https://browzwear.com/products/smartdesign/
- Clothier Design Source: http://www.clothierdesignsource.com/virtual-prototyping/  
- Clo3D: https://www.clo3d.com/  

In addition to 2D-to-3D approach, there has been a notable amount research focusing on 3D-to-2D design technique and related flattening methods that aim at enabling flattening of 3D garment surfaces into 2D patterns (Mok et al., 2016; Huang, 2011; Huang et al., 2012, Hong et al., 2017, Sayem et al., 2014). Pattern flattening for apparel production needs have proved to be a challenging task and commercial solutions are still mainly focused on the 2D-to-3D approach. Capabilities provided by 3D-related pattern flattening or unwrapping have been very limited in use for apparel production (Sayem et al., 2014). Solutions of this area have enabled designing simple garments. Despite identified challenges, there has been development in this area and some SW vendors have brought out benefits that can be achieved by utilising 3D CAD applications and related digital patterning in textile and apparel production. Nowadays, flattening can be applied, for example, in the technical textile industry. A good example is a solution called ExactFlat (https://www.exactflat.com/consumergoods/) that promise to provide a 3D-to-2D design solution, e.g., for scuba suits, backpacks, shoes and apparel. 3D DesignConcept software from Lectra is also capable of 3D-to-2D pattern unwrapping, which is mainly targeted for automotive seats design and interiors.

2.7.3 Barriers and opportunities

Reducing the number of physical samples by adopting virtual prototyping technologies is an obvious advantage. Papachristou and Bilalis (2017) have studied 3D virtual prototyping-related benefits from perspectives of 3D vendors, independent 3D consultancies, 3D experts in the apparel industry and academics. According to their study, advantages of 3D virtual prototyping are related to cost reduction, faster development, better communication, improved collaboration and better support for decision-making (Papachristou and Bilalis, 2017). According to the earlier study of Chittaro & Corvaglia (2003), 3D virtual prototyping technologies have the potential to reduce “time-to-market” and work costs, and additionally offers opportunities for utilising product visualisations directly on the web. Virtual fit simulation can be seen as an integral part of the 3D sampling process (see Figure 7). Lee and Park (2017) suggest that 3D virtual fit simulation technology enables technical designers to make preliminary fit analyses and check fit issues already in the early phase of prototyping. In addition, seamless integration of 3D models with pattern design supports the collaboration between designers and pattern makers and makes it possible to easily change from a 2D pattern to 3D model and vice versa (Papachristou and Bilalis, 2016b).
Properties of clothes set challenges for 3D simulation. The highly deformable and nonlinear nature of the cloth and cloth’s interaction with the human body require advanced features in 3D modelling software tools (Stepanovic et al., 2012). Technology need to be improved in many aspects for supporting more comprehensively apparel production. For example, collision detection – an effect familiar to realistic 3D video games – is needed for making it possible to create life-like garment details, like puffs, pleats and puffs, by designers (Papachristou and Bilalis, 2016b). This feature is currently available in some tools, for example, in the Clo3D tool. Papachristou and Bilalis (2017) have identified the challenges of 3D virtualisation from the perspective of vendors, independent users, academics, every day users and managers. Table 6 lists these disadvantages.

Table 6. Disadvantages of 3D virtualisation from different perspectives (Papachristou and Bilalis, 2017).

<table>
<thead>
<tr>
<th>Actor</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology providers-vendors</td>
<td>• Insufficient dedicated time and effort in adopting the new technology by companies</td>
</tr>
<tr>
<td>Entrepreneurs-independent users</td>
<td>• Accuracy of the solutions inadequate</td>
</tr>
<tr>
<td>Academics</td>
<td>• Lack of experienced users with technical knowledge</td>
</tr>
<tr>
<td>Managers-executives-professional users</td>
<td>• Huge workload related to content libraries for the project team</td>
</tr>
<tr>
<td></td>
<td>• Fabric properties related to the feel, drape and reaction on the body</td>
</tr>
<tr>
<td></td>
<td>• Lack of communication between different 3D software tools</td>
</tr>
</tbody>
</table>

It has been also identified that fit can also be a problem (Papachristou and Bilalis, 2017) and especially there can be challenges using 3D virtual fit simulation technology in simulating garment fit that is influenced by numerous factors including tensions or different types of fabric construction (Lee and Park, 2017).

In addition, in discussions with Finnish companies involved in the DICI project, the relatively low-quality of 3D models provided by some tools was criticised. It was mentioned that the quality of 3D models provided currently by some tools cannot be compared with 3D models familiar to digital games. This especially limits the use of generated 3D models for marketing purposes in digital channels.

2.7.4 Summary

3D virtual prototyping is becoming an integral part of digital product development in the apparel industry. Currently, many companies, like Adidas, Nike and Under Armour, use 3D virtual tools in their sampling process. The essential advantage of virtual prototyping is a reduction in “time-to-market” and cost savings achieved through a process that is more efficient compared to a traditional one. Currently, there is a wide range of 3D-based design tools available for apparel sampling processes and the quality of tools and 3D models is continually improving.

3D software tools used today in the apparel industry are commonly based on the 2D-to-3D approach, which requires 2D pattern making as a first step. Advancements in 3D CAD solutions and digital patterning in the future have a potential to change the production model in the apparel industry. However, research and development is still needed so that the 3D-to-
2D approach can be widely deployed and utilised. Currently, 3D flattening for directly generating 2D patterns is applied to some extent, but there is still a need especially for more advanced flattening methods that can be utilised more widely in a textile and clothing production. Altogether, integration of 3D CAD, digital patterning and digital printing can change the whole workflow and value chain in the textile and apparel industry in the future (Digital Patterning, 2017).

According to Papchristou and Bilalis (2017) future research should focus on identifying existing solutions provided by vendor companies and identifying needs of the early adopter companies regarding 3D technology.

**References:**


2.8 Ecosystemic approach – Digital platforms

2.8.1 Overview

The Prime Minister’s Office (VNK) has estimated that digital service ecosystems and platforms can form a key competitive factor for Finland. A digital platform can be defined as IT system and related collaborative practices with which different stakeholders — users/end customers, providers and other stakeholders — may create value together. The digital platform economy can be defined as a market where the business that relies on digital platforms has achieved significant — or dominant — market position (Ailisto et al., 2016).

Well-known examples of the platform companies are Microsoft, Google, Apple, Alibaba, Amazon, etc. A well-known example of a platform that is used widely in literature is the Apple platform (see e.g. Garcia-Swartz. & Garcia-Vicente (2015) and Hagui (2014)). The most common type of digital platform is a digital marketplace (Ailisto et al., 2016). These are, e.g. Tori.fi and Autotalli.com and platforms for clothing stores, like Zalando, and in Finland, Weecos and Ivalo. A digital marketplace coordinates demand and supply between different parties by means of digital solutions. Even though the product/service sale is the platform’s primary
objective, digital platforms often also allow open exchange of information before the actual product and service sales occur (Castren et al., 2016).

Platform ecosystem comprises three central roles:

- **platform owner:** typically a company that owns the platform and is responsible for its operation. Decides the rules for how the platform is used.

- **service/product providers:** stakeholders that offer their services/products in a platform.

- **users/customers:** stakeholders that use the services through the platform.

What are the typical features of a platform? This is needed to understand the dynamics of the platform economy. Typical features are (coverage and depth of the feature depends on the platform itself) (Ailisto et al., 2016):

- **Network effects:** network effect means that the benefit one gets from the usage of the platform depends on the number of other platform users (Garcia-Swartz & Garcia-Vicente, 2015). For instance, the number of available apps provided by the smartphone platforms (e.g. Apple and Google in their app shops) are the most important factor affecting consumers’ mobile platform (e.g. Apple vs. Google Android) choice decisions (Nikou et al., 2014).

- **Multisided platforms (MSP):** Multisided platforms are technologies, products or services that create value primarily by enabling direct interactions between two or more customer or participant groups (Hagui, 2014). There are two key characteristics of a multisided platform (Hagui, 2014):

  - each group of participants (“side”) are customers of the MSP in some meaningful way
  - the MSP enables a direct interaction between the sides.

In digital marketplaces these participants are naturally buyers and sellers whose interaction is facilitated by the marketplace provider (digital platform provider).

- **Complementaries:** It has been noted that the biggest revenue has been achieved in recent years in situations where business platforms have been opened up to third-party technologies, products and services. As the various commodities, products, services and applications complement each other and bring added value to the customer, they are complementary. Furthermore, experience has shown that a successful platform company that manages core platform components gets the largest share of revenue. Complementary services/providers may be, e.g. in the case of digital marketplaces, analytics services, advertisers, logistics, etc.

- **Cooperative and technical boundary resources:** Boundary resources are collaborative, legal, administrative and operational practices/agreements, as well as software tools and technical interfaces between the platform company and third parties. These interfaces are needed to allow a wider, heterogeneous set of companies to participate in developing and maintaining platform services.
2.8.2 Applicability in a textile and clothing industry

Digital platforms are dominantly marketplaces (Ailisto et al., 2016). These focus on B2B (Business-to-Business), B2C (Business-to-Customer) or C2C (Customer-to-Customer) business. Furthermore, it seems that new ecosystems and platforms are emerging especially around global textile industry trends like sustainability and ecological production. Next, a few platform ecosystems are introduced and discussed.

**Zalando**

Zalando is a German marketplace platform (B2C) for clothing companies selling clothes, shoes and other lifestyle products. Their platform is based on Zalando’s proprietary technology platform, ZEOS (Zalando E-commerce Operating System)(Zentes et al., 2017). Their future target is to build a service platform and ecosystem that brings the fashion industry together comprising consumers, brands and retailers, stylists and logistics service providers1. By building an ecosystem, Zalando can grow and at the same time create growth opportunities for other ecosystem partners as well. To enable this, Zalando has started the “Build” program that tries to integrate startup companies offering solutions to personalise the shopping experience and to boost inspiration. Their areas of interest include, e.g. sizing/fitting solutions, style/outfit generation, recommendation systems, and anything else that helps connect people to fashion2. Selected partners will have access to millions of Zalando customers across Europe and they will be provided with the APIs needed for the integration of complementary services into Zalando’s platform. This approach moves Zalando towards real MSP with new value-providing partners.

**Weecos**

Weecos is a Finnish marketplace platform (B2C) for clothing companies focusing on sustainability, i.e. clothes are manufactured ecologically and ethically. Weecos started as a clothing company selling their sustainable products in their own web-store. They expanded their offering by developing a marketplace platform where other clothing companies may set up their own web-store inside the marketplace and get visibility for their products and services. Therefore, Weecos has transformed from a pure clothing company to platform company.

According to Hagiu & Wright (2015) Amazon started as a pure retailer but has moved closer to a MSP model over time by enabling third-party sellers to trade directly with consumers on its website. Weecos has gone through somewhat similar development. First, they started as a web shop selling their own sustainable products, but then transformed into a marketplace platform focusing on sustainability. Focus on sustainability (market differentiation) is understandable because otherwise Weecos would have to compete with other large marketplace platforms (e.g. Amazon, Zalando).

Weecos has defined criteria for how to enter into the ecosystem (part of Weecos boundary resources). The process for selecting ecosystem partners is the following:

- A company contacts Weecos.
- Weecos sends a questionnaire to ensure that the company fulfils the criteria.
- If the criteria are met, the company receives registration information and can start to build a web-store.

In the future, Weecos's target is to expand the operation internationally. They want to provide a lifestyle service where people interested in ecological and sustainable lifestyles can discuss and make better purchasing decisions.3

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1 https://www.opuscapita.fi/uutiset/2017/muodikas-ekosysteemi
2 https://build.zalando.com/#home-about
3 http://ida365.fi/2013/10/08/weecos/
IVALO

IVALO⁴ is a Finnish marketplace platform (B2C) for clothing designers (companies) that is directed to slow fashion⁵. It is a free sales platform where IVALO takes care of the money transfers between a company and consumer and charges a small sales commission for the products sold⁶. They offer tools for companies (e.g. designer dashboard) to manage their products and orders in the marketplace.

Zadaa

Zadaa⁶ is a Finnish second-hand marketplace platform (C2C) especially targeted to clothes. Their business idea is to work as an intermediary between providers and customers just as Uber works as an intermediary for transportation services and Airbnb accommodation services. Service helps the user find the most suitable and comfortable clothes in the service. Each user inputs the exact size information and also the details of the clothes (the visibility of sensitive information may be restricted). Zadaa takes a small fee based on the price of the products sold, otherwise, the solution is free to use. The solution filters out the most suitable clothes among the products. When a vendor (private person) publishes its product, the solution is looking for the best possible buyer by size and style. Therefore, users do not see all clothes in the service, but only products that are recommended to them.

Fashion Cloud

Fashion Cloud is a startup founded two years ago in Hamburg, Germany. They provide a platform for digital cooperation between fashion brands and retailers⁷ (B2B). The platform ecosystem also includes some ERP providers (integrations).

For brand companies Fashion Cloud enables the control of all brands together on the same platform. This makes the distribution of content information (product information, stock levels) a much simpler process, as well as facilitates the availability of content for the retail partners.

For retailers, Fashion Cloud allows access to marketing and product images from more than 250 brands. Brands upload marketing material, product data and logos to the platform and set characteristics (such as season and expiration date). The premium account of Fashion Cloud allows direct API access to an image database enabling fully automatic product data flow into a retailers ERP system.

2.8.3 Barriers and opportunities

Digital platforms are currently predominantly marketplaces – but the potential is much higher. In such scenarios, the textile/clothing industry co-operates with different technology vendors and with the various actors in the supply chain so that each partner produces their own added value in the ecosystem. In such an environment, totally new services may be provided in B2B and B2C contexts. Zalando moves in this direction with its “Build” program² involving technology companies to create value-adding solutions into Zalando’s platform.

A wider ecosystem may comprise partners such as:

- Platform company

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⁴ https://ivalo.com/en/about
⁵ http://www.lily.fi/blogit/slow-f/mita-tarkoittaa-slow-fashion
⁶ https://zadaa.co/
⁷ https://fashion.cloud/en/
Companies providing electronic body measurement services
Companies offering digital textile patterns
Companies that provide digital printing or 3D printing
Data-analytical companies that provide analytics services, for example, to utilise customer data
Logistics service companies that provide transport services related to products

For instance, Hanuska et al. (2017) presents that smart clothing industry ecosystem may provide value to the individual person (situational and predictive analysis to improve performance, protect from injury) and to the business (trends, simulation to decrease costs and increase productivity). Such an analytics platform for the smart clothing industry ecosystem may include partners such as (Hanuska et al., 2017):

- Clothing manufacturers (incl. specialists), (e.g., Nike, Athos ….)
- Insurance providers (e.g., Cygna, Medicaid, Kaiser, etc.)
- Unions, (e.g., National Nurses United, National Basketball Players’ Union, etc.)
- Big data storage providers (e.g., Amazon AWS, Apple, Oracle, etc.)

What challenges can a platform company encounter when building a digital platform and associated ecosystem?

1. **failure to optimise “openness”:** the success of the platform depends on the value created by platform participants and how the platform company manages the platform openness (Van Alstyne et al., 2016). Here openness refers to the degree of access that the providers and customers have to a platform and what they are allowed to do there. If the platform policy is open, poor-quality contributions may destroy the value and reputation of the platform. However, if the policy is very restrictive, then the number of participants may be low. The openness can be controlled with cooperative boundary resources. For instance, Weecos has developed the entry criteria that are used to filter out providers that do not meet the sustainability requirements.

2. **problems to achieve critical mass:** a platform should leverage network effects – the more participants on the platform, the greater the value produced (Van Alstyne et al., 2016). A digital platform does not have to acquire just one group of participants, but it has to attract both customers and providers. However, these groups are interlinked. In the case of a digital marketplace, if you do not have customers in your platform, the providers (e.g. stores) are not interested in the platform. And if you do not have providers in your platform, the customers are not interested. This is a traditional chicken-egg problem. Overcoming this problem may require, e.g., monetary subsidies (free usage, etc. at the beginning) from the platform company to attract the partners to achieve critical mass.

3. **sharing the benefit:** having valuable interactions is the reason to participate on the platform (Van Alstyne et al., 2016). Therefore, the platform company should consider pricing as well as what value different partners get by participating in the platform. A simple rule for a platform company is to “take less value than you make” (Van Alstyne et al., 2016).
One of the most serious problems is that companies simply do not see the platform play at all (Van Alstyne et al., 2016). This means that companies stick to the idea of selling their products even though they could start to build up a platform business.

Based on our interviews in the DiCI project, it was stated that Finnish textile/clothing companies do not cooperate as much as they should. Leveraging ecosystems and digital platforms could offer significant potential for textile/clothing companies in Finland. The potential of platforms has been recognised also by decision-makers in Finland (Ailisto et al., 2016).

2.8.4 Summary

Digital platforms have been prominently marketplaces, such as Amazon and Tori.fi. However, in the future technological solutions, such as sensors, data analytics, etc., become part of everyday life and products. Companies specialise in their core competencies and, therefore, it can be estimated that new ecosystems are emerging comprising business, logistics and technology companies. It has been stated by Papachristou and Bilalis (2016) that the clothing industry needs to create a new ecosystem including strong partnerships between technologists and fashion designers. Furthermore, it seems that new ecosystems and platforms in the textile industry are emerging around global trends – like sustainability and ecological production.

Companies that move towards a digital platform business need to overcome several challenges. Companies need to rethink their business models, acquire new competences and reinforce co-operation between partners. The platform needs to achieve critical mass to be viable, provide reasonable business logic for partners and attract new participants (network effects) to enable growth. The platform company needs special competence regarding cooperative and technical boundary resources to be able to orchestrate platform development and partners during the lifecycle of the platform towards mutual benefits.

As presented in a previous section, there are already several digital platforms in Finland and some of them are internationalising (e.g. Weecos). This is a desirable development process in Finland since successful platform companies have control over the platform (entry criteria, pricing model, etc.) and they get a constant share of revenue from the success of the platform ecosystem.

References:

Ailisto, Heikki (toim.); Collin, Jari (toim.); Juhanko, Jari (toim.); Mäntylä, Martti (toim.); Ruutu, Sampsa (toim.); Seppälä, Timo (toim.); Halén, Marco; Heikkanen, Kari; Hyytinen, Kirsi; Kiuru, Eeva; Korhonen, Heidi; Kääriäinen, Jukka; Parviainen, Päivi; Talvitie, Jaakko. 2016. Onko Suomi jäämässä alustatalouden junasta?. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 19/2016. Valtioneuvosto. [Link]


Garcia-Swartz, D. & Garcia-Vicente, F. (2015). Network effects on the iPhone platform: An empirical examination, Telecommunications Policy. [Link]


3. Results of the DICI survey

This section introduces the results of a web-based survey that was conducted at 24.5. – 24.6.2017 as part of the DICI project. The aim of the survey was to analyse experiences, thoughts and goals of Finnish apparel, textile and fashion companies relating to digitalisation; how digitalisation affects companies’ businesses and operating environments. One of the special focuses was to identify companies’ expected benefits, targets and challenges now as well as to clarify what kinds of activities have been planned in the near future. The summary slide set of the survey results in Finnish have been included as an attachment in this deliverable (Annex 1).

In addition to the DICI survey, several persons from various positions in a total of seven textile and clothing companies were interviewed during spring-autumn 2017. The interviews concerned the same topics as the survey questionnaire but they enabled discussion about each of the questions with details for providing deeper and larger understanding of the topics. These interviews have been integrated into analyses of the DICI survey topics in this section.

3.1 Background of the survey

The questionnaire link of the DICI survey was sent via email, asking respondents to send the email message forward at the end of May 2017. The study was also informed and advertised via the newsletter of the Finnish Textile and Fashion Organisation. In all, a total of 55 respondents answered the survey.

The majority of respondents' businesses focused on men, women and children's wear, as shown in the Figure 8.
While asking about phases of business value chain in which companies were acting, it was notable that almost half (47%) of respondents informed that their business covered all phases from design to delivery (Figure 9); delivery of products was most commonly excluded. In addition, a third (31%) of respondents also identified preliminary design and data collection as one of their focus areas. Furthermore, only 15% of respondents informed that they had outsourced their production and finishing phases. Their business process was based on the design process with marketing and sales activities. The following figure depicts the distribution of responses based on the survey results.

Figure 8. Areas of business focus by companies (N=55).

While analysing organisations’ sizes, most respondents (~82%) represented small companies (under 30 persons) as illustrated in the following figure (Figure 310). In addition, over half (~51%) of all respondents represented companies with under 10 personnel.

Figure 9. Value chain phases on which companies’ business were focused (N=55).

Roadmap for boosting the international growth of Finnish clothing and textile industry: Part 1
In general, small companies are common in Finnish textile and clothing sector. In fact, companies with over 10 persons cover approximately only 9% of all organisations in the textile and fashion industry, even though these companies produce almost 60% of the turnover of the domain (STJM, 2017). However, it is important to recognise that STJM’s statistics include companies that fulfilled specific criteria. These criteria exclude all self-employed persons, even though the amount of these covers 38% of all companies in the domain. The reason for this exclusion is clear, as their turnover accounts for only 3%, and staff 5%, of all companies. The situation is created because most of these companies have been established by their main designer, but have not been able to enlarge their business (Lille, 2010).

In our survey, also self-employed persons have been included in the results. That is why the portion of staff under five persons is 38% (21 respondents) of all replies. Furthermore, in our survey, only five (5) respondents (9%) informed that their organisations have over 100 staff persons. Even if the result is well in line with the general deviation of organisation sizes in Finland, the sample is not sufficient for making exact conclusions based on these results. This is important to remember when comparing survey results based on organisation sizes later in this deliverable (in Section 3.4).

For the overall result, the basic statistical distributions of the survey have been included in Annex 1. For statistical analysis, data was classified based on respondents’ organisation size as follows:

- small organisations with 0–10 persons: 28 in total,
- medium organisations with 10–100 persons: 22 in total,
- large organisations with over 100 persons: 5 in total.

### 3.2 Current use of digital solutions in a customer interface

The survey yielded the main reasons why companies exploit digitalisation or new technology solutions in their businesses (Figure 6, Annex 1). The top five main reasons identified are as follows (the amount of responses in brackets):

- It has created new possibilities for expanding current business (e.g., web store). (37)
- It has increased visibility and desirability of their products or services. (15)
- It has supported profiling a company as a forerunner and an innovative company. (12)
- It has created new customer relationships. (11)
- It has enabled development of a new service or product concept(s) or even totally new business. (10)
- It has improved a company's own (internal) efficiency (with new IT-systems, process changes, etc.). (10)

The survey pointed out that digitalisation exploitation is ongoing in the Finnish textile and apparel industry, even if it still seems to be in the beginning phases. Obviously, a few great examples exist that can hopefully serve as a facilitator and innovator to others. Currently, digitalisation has been well exploited in a customer interface, especially with social media channels, web stores and web advertising.

The following digital solutions in a customer interface were typically exploited based on our survey (the question was multi-choice; N=55):

- Social media channels. (49 replies; 89% of all respondents)
- Web stores. (45; 82%)
- Web advertising. (37; 67%)
- Loyalty system. (17; 31%)
- Mobile applications. (15; 27%)

While asking how (or by whom) their company’s solutions had been developed, the most typical answer was that they did this by themselves. Especially, utilisation of social media channels, web advertising and loyalty systems had been produced in-house (Figure 4, Annex 1). The result raises the assumption that these kinds of loyal customer systems are not very complicated, but are rather customer register-type solutions without complicated data analytics possibilities.

3.3 Current utilisation of digitalisation in business

The survey pointed out that customer data analyses were the most common way to utilise digitalisation in current business (Figure 5 in Annex 1). The deviation based on our survey was as follows (multi-choice; N=55):

- Analysis of customer data (shopping data, focused marketing to regular customers,…). (29; 53%)
- Analysis of online customer behaviour (e.g. time used in web pages and interesting products). (28; 51%)
- ERP (Enterprise Resource Planning software). (19; 35%)
- Digital printing on fabric or clothing. (16; 29%)
- Automation in cutting process. (16; 29%)

While further clarifying how the digital solutions that were related to customer data analyses (the first and second choices above) had been developed, approximately half of respondents answered that they did this by themselves. Instead, solutions related to ‘ERP systems’ and ‘Automation in cutting process’ had been typically produced via a complete commercial solution. Digital printing solutions had been produced by utilizing sub-contractor(s).

Even if customer data analyses were mainly done by oneself with in-house knowledge, the result supports the most important reason to exploit digitalisation in their business (Figure 6, Annex 1): Digitalisation has created new possibilities for expanding current business (e.g., web store). (37; 67%). This reason is centred around the “value proposition” element of the well-known Business Model Canvas.
The survey clarified also the most common challenges or obstacles related to why exploitation of digitalisation or new technologies was seen as problematic in companies’ businesses (Figure 7 in Annex 1). The respondents identified the most challenging topics as follows (multi-choice; max 3 choices could be selected; N=55):

- We do not have time or resources to clarify/to be familiar with possibilities. (29; 53%).
- We lack skilled staff. (22; 40%)
- We have just started to study and clarify possibilities and alternatives. 21; 38%)
- Our financial resources do not allow exploitation. (16; 29%)
- Technology possibilities are not known. (15; 27%)

The survey pointed out that challenges and obstacles were concentrated on lack of knowledge and resources (time, money and skills persons). The result is very understandable as the Finnish textile, apparel and fashion business is small entrepreneur-dominated (STJM, 2017).

3.4 Actions in near future

The survey clarified general digitalisation-related activities that respondents believed they would be processing in their organisation within three years (illustrated in Figure 8, Annex 1):

- Studying existing opportunities and comparing competitors (benchmarking). (32; 58%)
- Increasing knowledge and skills (incl. recruiting). (31; 56%)
- Improving organisation's own processes through digitalisation. (31; 56%)

These results show that exploiting digitalisation possibilities is still in a quite early phase. The results correlate with the question “What are the most significant challenges for exploiting digitalisation in your companies?” mentioned before and illustrated in Figure 7, Annex 1.

While clarifying customer interface digital solutions with the highest probability of being exploited in near future in the respondents’ companies, the results were as follows (Figure 10, Annex 1) (the question was multi-choice; N=55):

- Mobile applications. (20 replies; 36% of all respondents)
- Use of measuring data given by a customer on an online service for size recommendations. (17; 31%)
- Modelling clothing and textiles in digital services. (15; 27%)
- Customer loyalty system. (15; 27%)
- Digital customisation service of products for the customer. (13; 24%)

The results showed that large organisations will concentrate on exploiting ‘Mobile applications’ and ‘Digital customisation service of products for the customer’ (Figure 11 in Annex 1), while small organisations will concentrate on exploiting ‘Use of measuring data given by a customer on an online service for size recommendations’ and ‘Customer loyalty system’.

While clarifying digitalisation and new technology solutions with the highest probability of being exploited in companies’ businesses in the near future, the results were as follows (Figure 12 in Annex 1) (the question was multi-choice; N=55):

- Analysis of customer data (shopping data, focused marketing to regular customers,…). (18; 33%)
- 3D pattern making and modelling in design. (13; 24%)
- Digitalisation in storage and logistics. (12; 22%)
- Analysis of online customer behaviour (e.g. time used in web pages and interesting products) (12; 22%)
- Digital printing on fabric or clothing (11; 20%)
The results also showed that large organisations will concentrate on ‘Digitalisation in storage and logistics’ and ‘Utilisation of 3D in design’, while the smallest organisations will concentrate on exploiting ‘Analysis of customer data’ and ‘Digital printing’ possibilities (Figure 13 in Annex 1).

When identifying the estimated timeframe for upcoming activities, the result was unambiguous: the possibilities of digitalisation will be increasingly exploited in the near future, as shown in Figure 41.

![Figure 41. Exploitation of digitalisation in the near future (N=55).](image)

As shown in Figure 41, 19 (35%) of respondents estimated that exploitation of digitalisation will 'Stay the same' within the next year. However, most of them believed that exploitation will increase a bit or much after one year.

Only 5 (9%) of respondents argued that in their organisation exploitation will be at the same level in the near future. In a more detailed examination, only one respondent indicated that there will be no change in their exploitation of digitalisation.

As a summary of the survey results, Finnish clothing, textile and fashion companies have now begun to leverage the potential of digitalisation. The results indicated that digital solutions companies were capable of implementing in-house are the most prevalent, along with solutions that were reasonably agile and flexible to implement, such as social media, online shopping and web marketing functions. However, there is a lack of expertise, skills and resources, especially, in small companies. The Finnish textile and fashion sector is dominated by SMEs and that must be taken into account when developing support actions or functions in this domain.

**References:**


4. Future insights

This section summarises future insights of the Finnish clothing and textile industry in utilising digitalisation.

4.1 General views into digitalisation in Finnish textile and clothing industry

Finnish textile and clothing companies are already leveraging the potential of digitalisation, especially in the areas of social media, online shop and web marketing. The results of our survey indicate that currently the most utilised areas of digitalisation covers functions and solutions that companies were capable of implementing in-house, along with solutions that were reasonably agile and flexible to implement. The companies also view that the use of new technologies had created new opportunities for expanding their existing business (e.g. an online shop) and increased the visibility and attractiveness of their products and services.

Digitalisation will result in significant changes in the textile, clothing and fashion industries thanks to innovations such as 3D modelling, data analysis and product customisation. The winners of the future will be the companies that utilise new technologies in their business and discover new, innovative ways of fulfilling the needs and expectations of their customers. According to our survey with the Finnish textile and clothing industry, Finnish companies are adopting novel digitally-enabled solutions for boosting their business. Results of our survey suggest that all Finnish companies, from one-person companies to bigger business actors, have intentions to develop their business in one way or another by utilising digitalisation in the future. The focus and scale of digitalisation varies typically based on the size and resources of the company. Finnish companies are interested in both developing their service and product offering and internal processes through means of digitalisation. According to the results of our survey, 30 out of 55 (~55%) companies are especially focusing on enhancing or improving their current products and services and 31 out of 55 (~56%) of companies were interested in accelerating the company’s internal processes by utilising digitalisation in the future. The willingness for utilising digitalisation emerges also in a recently increased amount of Chief Digital Officers (CDOs) in the apparel companies.

Digitalisation emerges in numerous wider trends in textile and clothing industry. For example, it can be seen as an essential part of sustainability, which has been one of the most visible trends in recent years in the textile and clothing industry. Customers have started looking at the ethical values and recycling of products, and these have even joined price and availability as selection criteria for products and services. Digitalisation enables and promotes transparency and traceability in production and distribution chains. Research and development, for example on fibres, 3D virtual sampling, 3D printing and predictive data analytics are all connected to a sustainability trend. The above-mentioned technologies support more ecological methods in different phases of the product lifecycle. There are also networks/ecosystems built around the sustainability theme in the textile and clothing industry.

The omni-channel concept is one of the trends that has gained a lot of attention in recent years. It can be seen as an expansion for the multi-channel environments as it aims at providing seamless customer experiences within and between channels, such as web stores, mobile applications and brick-and-mortar. In practice, the spread of consumer behaviour across multiple channels has created demand for new innovations and methods of commerce. Companies that will be able to combine different channels of influencing consumers and consolidate their brand extensively through different channels, both in the domestic and international markets, will achieve the greatest success. The novel and successful marketing and sales channels and campaigns implemented by Finlayson are a good example of this. The company has also been able to react quickly to current phenomena, such as by making lion products for the IIHF World Championships and reacting to the discussion on wage inequality between the genders with the ‘Woman’s Euro’ campaign. Some Finnish companies have also
invested in their internal projects with a focus on an omni-channel approach and are planning completely new types of digital services for consumers, like digitally-enabled personal style curation service.

Crowdsourcing has gained globally an increasing interest in the textile and clothing industry. In Finland, Nokian Neulomo has used crowdsourcing for choosing the colours of models for production. In addition, Finlayson has been using principles of crowdsourcing in their design competition for designing the Finnish lion. US-based Spoonflower, which is focused on custom-printed fabrics, has also promote a design challenge for harnessing external resources for creating new pattern designs. Nowadays, companies can easily outsource, without large investments, some of their functions to online communities for crowdsourcing, for example through their social media channels and web sites. Crowdsourcing can also be seen as useful for marketing purposes and enabling more active customer participation. Even though crowdsourcing is a promising approach, utilisation of its possibilities is still limited by Finnish textile and clothing companies.

Generating value from digitalisation requires deeper collaboration between technology companies and apparel companies in the future. In addition, companies must identify the high-value cases for digitalisation and rethink their processes as an integral part of digitalisation activities in order to capture the benefits of digital innovations. A closer collaboration between technology and apparel companies can be enhanced, for example, through innovation events. For example, Finnish textile and fashion (in Finnish: STJM) has organised a hackathon event in 2017 for finding novel solutions to challenges of the future and to find new tools to promote the success of the Finnish textile and clothing industry. Marimekko also recently organised a hackathon focusing on exploring the use of AR and VR technologies in the textile industry. Marimekko has also recently launched their ‘Virtual Marimekko Home’ service. It can be expected that the hackathon type of events that connect experts from textile and technology sectors will be more common in the coming years.

4.2 Insights into selected digitalisation topics of the Finnish textile and clothing industry

This section outlines how Finnish companies involved in our survey view their near-future activities regarding digitalisation and outlines the first version of the roadmap that will be enhanced in the second phase of the DICI project. The companies were asked what kind of elements of digitalisation they would most likely utilise in the future. Table 7 summarises seven topics that gained attention in the industry and related activities that attracted companies’ near-future investment interests. Additionally, the right-side column lists relevant technologies and trends that have a potential impact on these near-future activities.

The first four rows represent general topics that are related more to companies’ overall businesses and the last three rows represent specifically customer interface-related topics. A share of interest among companies to specific activities is shown in brackets in front of every near-future activity.

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8 http://100leijonaa.fi/
9 https://www.stjm.fi/ajankohtaista/hae-mukaan-texhack-innovaatiotapahtumaan/
10 https://www.architecturaldigest.com/story/marimekko-design-hackathon-explores-virtual-reality-for-textiles
Table 7. Companies near-future activities regarding digitalisation.

<table>
<thead>
<tr>
<th>Topics</th>
<th>Near future activities based on the survey; N=55 (Section 3)</th>
<th>Emerging trends and technologies based on SoA (Section 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Customer data</td>
<td>(33 %) Analysis of customer data (shopping data, focused marketing to regular customers) (22 %) Analysis of online customer behaviour (e.g. time used in web pages and interesting products) (16 %) Analysis of customer behaviour in retail stores</td>
<td>- Indoor positioning - Big data analytics - Predictive analytics - Artificial Intelligence</td>
</tr>
<tr>
<td>2. Digital printing</td>
<td>(20 %) Digital printing on fabric or clothing</td>
<td>- Technology mature enough for a wider adoption</td>
</tr>
<tr>
<td>3. 3D virtual product development /prototyping</td>
<td>(24 %) 3D pattern making and modelling in design (16 %) Utilisation of 3D models in pre-marketing</td>
<td>- Development of flattening methods (3D-to-2D approach) - Advanced 3D modelling for textures and physics</td>
</tr>
<tr>
<td>4. Storage and logistics</td>
<td>(22 %) Storage and logistics</td>
<td>- Tracking and positioning technologies (e.g. RFID-based systems) - People-based marketing</td>
</tr>
<tr>
<td>5. Digital marketing</td>
<td>(36 %) Mobile applications (16 %) Web advertising (15 %) Digital signage</td>
<td>- Interactive digital signage</td>
</tr>
<tr>
<td>6. Digital customisation</td>
<td>(24 %) Digital customisation service for customers</td>
<td>- Mass customisation related solutions - Advanced web-based customisation tools</td>
</tr>
<tr>
<td>7. Digital fitting solutions</td>
<td>(31 %) Use of measuring data given by a customer on online service for size recommendations (16%) Digital fitting services (virtual fitting, AR) (18 %) Utilising 3D scanning in collecting dimensions from a customer</td>
<td>- 3D scanning - Curation and recommendation services - VR/AR visualisations - Advanced 3D modelling for textures and physics</td>
</tr>
</tbody>
</table>

Better customer understanding can be built on advanced data analytics. Companies involved in our survey were interested in utilising customer-related data from multiple contexts in the near future. In general, analysis of customer data was seen as interesting among companies. Both analysis of customer behaviour in the online and physical store environment was seen as being among near-future activities. There are existing and emerging solutions regarding customer data collection and analytics, which are not yet used commonly by Finnish textile and clothing companies. In general, predictive analytics provide a completely new set of possibilities for companies to plan their businesses. The use of these solutions in the future will have an impact on the whole process from the early planning phase to sales and marketing of products. Artificial intelligence is a future trend that should be included in companies’ longer-term digitalisation plans regarding utilisation of data. It is notable that several foreign companies in the fashion sector already utilise AI-based analytics in their business. Some of these services have been developed in-house, but there are also numerous big data analytics companies offering their solutions for the fashion sector.

Globally, digital printing has become more common steadily, but rather slowly. Digital printing is a relatively mature technology and digital textile printing services have become more common in recent years in Finland. It has been estimated by many sources that the increase in the use of digital printing will continue in the coming years. Our survey also shows that Finnish companies intend to utilise digital printing on fabrics and apparel in the near future.
There are also Finnish digital textile printing service providers that have knowledge and resources for high-quality digital printing.

3D virtual prototyping or sampling – as it is often called in the apparel industry – has aroused a wide interest in the textile and clothing industry. Based on our survey, many Finnish companies are going to utilise 3D technologies in their product development. Companies involved in our study are especially interested in utilising 3D modelling in design and pattern making phases. In addition, many Finnish companies see utilisation of 3D models for pre-marketing purposes as a near-future activity. In general, 3D models can support content creation for social media and advertising purposes.

Storage and logistics are critical activities in the end phase of a value chain. For example, RFID- and GPS-based solutions have been available already for these purposes and they have been used in many industries generally for optimising warehousing and tracking transportation of goods. Finnish companies involved in the study were clearly interested in utilising new technologies that can improve their effectiveness in the area of storage and logistics. Commercial solutions are already available to be used for optimising warehousing and logistics, and especially companies that have a wider distribution can benefit significantly from these technologies.

Digital marketing is the marketing of products and services through a wide range of digital channels covering web, mobile phones, digital displays and other digital media. Digital marketing has naturally moved towards personal mobile devices during recent years. Maybe the most significant benefit in mobile marketing is that it provides a way for location-specific marketing and a more personal channel to approach customers. Digital marketing services are nowadays widely available commercially and social media has nowadays an essential role in this area. Finnish companies are already utilising many possibilities of digital marketing and it seems that there is a high level of interest in further investments for developing digital marketing in Finnish companies. Customer data analytics is strongly connected to digital marketing, for example through profiling. Altogether, utilisation of advanced customer data analytics and people-based marketing approach provide wide opportunities for developing digital marketing in companies.

The Finnish clothing and textile industries’ interest in creating benefit for their customers through customisable products has been growing. At the same time, consumers are more interested in individual and customised clothing. According to our survey, many companies considered that they would like initiate near-future activities related to developing digital customisation services for their customers. There are already scenarios outlining how mass customisation could be accomplished by utilising a wide range of different technologies in different phases of production, but concrete examples of utilising these developing technologies through the whole production process is harder to find.

As described in Section 2, there is a wide range of solutions regarding digital fitting, which can also be a part of customisation services. Finding well-fitting clothes, especially in a web shop, is a commonly identified challenge. Our survey shows that Finnish companies are interested in utilising different types of solutions – including manually entered measurements, 3D body scanning and VR/AR-based fitting services – in the near future. In recent years, there have been clear advancements in digital fitting solutions and there are also technology companies in Finland that provide their digital body measurement services for apparel companies.

Interested towards an ecosystemic approach was also highlighted in our survey through companies’ high interest towards identification of potential partners and collaboration networks (47 %). A noteworthy feature of the Finnish textile and fashion sector is that it is dominated by SMEs. Digitalisation will open the global marketplace to companies of any size and enable entirely new marketing and sales methods. For example, the recently launched Finnish-based international e-commerce and marketing platforms, such as IVALO and Weecos, have been able to achieve global visibility, growth in their turnover and international sales. These
marketplaces can be seen as platforms for ecosystems through which also smaller companies can gain better visibility for their brand in global markets.

Digitalisation will inevitably continue to transform the clothing and textile industries in the future as well. Digitalisation will become more crucial in every phase of the value chain and will change many traditional operations in different sectors of the industry. In the future, production efficiency, fast reactions to current phenomena, sustainability and the ability to meet the personal demands of consumers will be the prerequisites for success. Thanks to its agility, small production series and utilisation of digitalisation, the Finnish clothing and textile industries have new potential in this competition. Yet, closer collaboration between professionals from the textile and clothing domain and technology experts is needed to create a lasting success through digitalisation for the industry in Finland. In addition, creating a successful business requires courage from companies to invest more in digitalisation and pilot novel solutions in the future.

Major international companies in the textile and clothing industry are forerunners in adopting digitalisation in their business. They have been deploying different elements of digitalisation actively in their business. Despite the benefits achieved through digitalisation thus far, there are still major challenges, such as integrating digital technologies into everyday operations. In other words, there is still a lot of work to do toward unlocking the potential of digitalisation for textile and clothing businesses. Overall, Finnish companies seem to be aware of the crucial role of investing in digitalisation for developing their businesses. As one CEO of the Finnish fashion company stated: “Digitalisation is a must if you want to survive”.
ANNEX 1 – The summary of the DICI survey

Digitalisaatio vaatetus- ja tekstiilialla - kyselyn tulosyhteenveto

6.10.2017
Tihinen Maarit, Senior Scientist, PhD
Data-driven solutions, Digital transformation
VTT Technical Research Centre of Finland
Digitalisaatio vaatetus- ja tekstiilialla 2017

- Digitalisaatio vaatetus- ja tekstiilialla – kysely toteutettiin kevään ja kesän 2017 aikana.
- Kyselyn laadittiin osana Tekesin tukemaa DICI-projektia (DICI – Competitiveness from digitalisation in clothing industry) ja sen toteutti VTT.
- Varsinainen kysely oli avoinna kuukauden: 24.5. – 24.6.2017:
  - Linkki kyselyyn lähetettiin sähköpostijakeluistojen avulla; kyselyn linkkiä kehotettiin myös edelleen lähetettämään.
  - Kyselyä markkinointiin myös Suomen Tekstiili & Muoti –uutiskirjeessä.
  - Kyselyyn vastasi yhteensä 55 henkilöä.
Digitalisaatio vaatetus- ja tekstiilialla

Kuva 1. Mihin toimialaan yrityksen liiketoiminta fokusoidaan? (N=55)

5.10.2017
Digitalisaatio vaatetus- ja tekstiillalla

| Tapahtuma                |numero
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<td>Jäljetti</td>
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<td>Jokin muu, mitä?</td>
<td>4</td>
</tr>
</tbody>
</table>

Kuva 2. Mihin arvoketjun vaiheisiin yrityksen liiketoiminta kohdentuu? (N=55)

5.10.2017
Digitalisaatio vaatetus- ja tekstiilialla

- Suurin osa vastaajista ehdotti varsin pieniä suomalaisia yrityksiä.
- Yli puolet vastaajista (51%) oli yrityksistä, joissa työntekijöiden lukumäärä Suomessa oli alle 10 työntekijää.
- Tarkastellaessa työntekijöiden lukumäärää m: yrityksen kansainväliset toimipisteet eroavat olisi havaittavissa.
- Yli 100 henkilön yritys on kyseessä pieni (vain 5 vastauksesta), otoksien huonon edustavuus huomioitava yrityksen kantakaudeissa (kelle 11 ja 13 ja 15).

Kuva 3. Yrityksen työntekijöiden lukumäärä Suomessa (N=55)

5.10.2017
### Digitalisaatio vaatetus- ja tekstiillalla

<table>
<thead>
<tr>
<th>Use this decision support tool</th>
<th>We do it ourselves</th>
<th>We buy it from others (e.g.)</th>
<th>We order it partially and support</th>
<th>Some other way</th>
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**Kuva 4. Mitä digitalisoinnissa asiakaspalvelun ratkaisuja ollut hyödynnetty liiketoiminnassa? (N=55)**

5.10.2017

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Roadmap for boosting the international growth of Finnish clothing and textile industry: Part 1
Roadmap for boosting the international growth of Finnish clothing and textile industry: Part 1
Digitalisaatio vaatetus- ja tekstiilialla

Kuva 6. Tarkoimmatsyyt miksi digitalisaatiota on hyödynnetty yrityksen liiketoiminnassa? (N=55)

Roadmap for boosting the international growth of Finnish clothing and textile industry: Part 1
Digitalisaatio vaatetus- ja tekstiiliyllä

Kuva 7. Suurimmat haasteet / ostot (maks. 3) digitalisaation hyödyntämisessä (N=55)

Roadmap for boosting the international growth of Finnish clothing and textile industry: Part 1
Digitalisaatio vaatetus- ja tekstiiliyksellä

1. Omat prosesseissa
2. Osallistuen (mi. rekryointi) ja
3. Tutkitaan mahdollisuuksia, järjestelmiin liittyvän
4. Nytystä pelästymisen ja
5. Lisätään liiketoimintaa
6. Identifioitaan potentiaalisia kumppaneilla ja

Kuva 8. Kaikki toimenpiteet, joita yrityksessä tullaan toteuttamaan läihivyösuina (N=55, monivalinta)
Kuva 9. Vertailu: Kaikki toimenpiteet, joita yrityksissä tullaan toteuttamaan lähinnäsa (N=55, monivalinta) (Ryhmätilypseneineen organisation kokon, pyydet kuval vastausten procentualista osuutta suhteellustaulu oman ryhmän vastausten lukumäärän)
Digitalisaatio vaatetus- ja tekstiiliyhdys

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<td>Digitaliset sovituspalvelut (virtuaalisovitus, lisätty todellisuus-AR)</td>
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<td>Asiakkaan syöttämien mittatoimien käyttö onlinepalvelussa kokosuositukissa</td>
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<td>Asiakkaan mitoitten kerääminen 3D-skannauksella</td>
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<td>Jokin muu, mikä?</td>
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1. Mobillisovitukset
2. Asiakkaan syöttämien mittatoimien käyttö onlinepalvelussa kokosuositukissa
3. Kanta-asiakasjärjestelmä
4. Tuotteiden digitaalinen kustomointipalvelu

Kuva 10. Lähitulevaisuus: Mitä asiakasrajojakin ratkaisuja tulette todennäköisesti hyödyntämään (N=55)

5.10.2017
Kuva 11. Vointiliitäminen: Mitä asiakaspalveluun ratkaisuja tulojattomuutta hyödynnettäisi (N=55, monivalinta)
(Ryhmäkriteerien perusteella organisaation koko, pyynnöt kuvaa vastausten prosentuaalistaa osuutta suhteellisena oman ryhmän vastausten lukumäärästä)
Digitalisaatio vaatetus- ja tekstiillalla

Roadmap for boosting the international growth of Finnish clothing and textile industry: Part 1
(Ryhmästi perusteen organisaation koko; pyydetään kuvaa vastausten prosentuaalista osuutta suhteuttuna omalle ryhmälle vastausten lukumäärillään)
Digitalisaatio vaatetus- ja tekstiilialla

- Digitalisaation hyödyntäminen tulee selvästi kasvamaan lähimmän kolmen vuoden aikana
- Vastaajista 19 (~35%) ilmoitti että hyödyntäminen pysyy ennallaan lähimmän kolmen vuoden aikana
  - Heistään suurin osa ilmoitti että hyödyntäminen kasvaa ennen kuin kasvaa paljon
  - 1-3 vuoden tai yli 3 vuoden kuluttua
- Vastaajista 5 (~9%) ilmoitti että hyödyntäminen pysyy ennallaan (ei vähene, eikä kasva) lähitulevaisuudessa
  - Vain yksi vastaaja ilmoitti, ettei muutosta tapahtu tarkan tietojen mukaan
  - Kaikki ilmoittivat että hyödyntäminen tulee kasvamaan kolmen vuoden kuluttua
  - Neljä vastaajaa, jotka ilmoittivat että hyödyntäminen pysyy ennallaan yli 3 vuoden kuluttua
  - Hetta digitalisaation hyödyntäminen olisi järjestävää ja kasvavaa lähimmän kolmen vuoden aikana.

Kuva 14. Arvio, miten digitalisaation hyödyntäminen etenee lähitulevaisuudessa (N=55)
Digitalisaatio vaatetus- ja tekstiilialla:
- mitä on jo tehty yrityksissä?

- Digitalisaation mahdollistamista asiakasrajapinnan ratkaisuista oli eniten hyödynnetty:
  - Sosiaalisen median kanavat;
  - Verkkokauppa;
  - Web-mainonta.

- Digitalisaation ja uusien teknologioiden ratkaisujen hyödyntämistä liiketoiminnassa oli tehty eniten:
  - Asiakastiedon analyysit (ostotiedot, fokusoitu markkinointi kanta-asiakkaille,…);
  - Asiakkaiden onlinekäyttäytymisen analyysit (esim. web-sivuilla vietetty aika ja asiakkaiden tekemät tuotteiden tarkastelut);
  - ERP (toiminnanohjausohjelmisto).
Digitalisaatio vaatetus- ja tekstiilialla: - suurimmat haasteet tai esteet?

"Valitse suurimmat haasteet tai esteet (maks. 3), miksi digitalisaation tai uusien teknologioiden hyödyntäminen koetaan ongelmalliseksi yrityksenne liiketoiminnassa?"

- Ei ole aikaa, eikä resursseja tutustua ja perehtyä mahdollisuksiin. (~53%)
- Puute osaavista henkilöistä. (~40%)
- Mahdollisuksien ja vaihtoehtojen selvittäminen vasta käynnissä. (~38%)
- Taloudelliset resurssit eivät mahdollista hyödyntämistä. (~29%)
- Teknologioiden mahdollisuudet eivät ole tiedossa. (~27%)
Digitalisaatio vaatetus- ja tekstiilialla: - tärkeimmät syyt hyödyntämiselle?

- Luonut uusia mahdollisuksia olemassa olevan liiketoiminnan laajentamiseen (esim. verkkokauppa) (~67%)
- Lisännyt tuotteiden ja palvelujen näkyvyyttä ja haluttavuutta. (~27%)
- Tukenut yrityksen profiloitumista ja brändiä edistyksellisenä ja innovatiivisenä yrityksenä. (~22%)
- Luonut uusia asiakkuuksia. (~20%)
- Parantanut yrityksen sisäistä tehokkuutta (uudet tietojärjestelmät, prosessien muutokset, ym.). (~18%)
- Mahdollistanut uusien palvelu-/tuotekonseptien tai kokonaan uuden liiketoiminnan kehittämisen. (~18%)
Digitalisaatio vaatetus- ja tekstiilialla: toimenpiteet lähivuosina

"Valitse kaikki ne toimenpiteet, joita yrityksessäne tullaan toteuttamaan lähivuosina?"

- Yrityksen koko alle 10 henkilöä (N= 28):
  - Lisätään tietämystä ja osaamista (ml. rekryointi).
  - Identifioidaan potentiaalisia kumppaneita ja yhteistyöverkostoja.
- Yrityksen koko 10-100 henkilöä (N=22):
  - Tehostetaan yrityksen omia prosesseja digitalisaation avulla.
  - Tutkitaan olemassa olevia mahdollisuksia sekä verrataan kilpailijoita (benchmarking).
- Yrityksen koko yli 100 henkilöä (N=5):
  - Laajennetaan tai paranetaan nykyisiä palveluja tai tuotteita digitalisaatiolla hyödynämällä.
Digitalisaatio vaatetus- ja tekstiilialla: 
- asiakasrajapinnan ratkaisut

"Arviointi, mitä luetellusta asiakasrajapinnan digitalisaation ratkaisuja tuette todennäköisimmin hyödyntämään lähitulevaisuudessa?"

- Yrityksen koko alle 10 henkilöä (N=28):
  - Asiakkaan syöttämien mittatietojen käyttö onlinepalvelussa kokosuosituksissa.
  - Kanta-asiakasjärjestelmä
- Yrityksen koko 10-100 henkilöä (N=22):
  - Mobiilisovellukset.
  - Vaatteiden tai tekstiilien mallintaminen digitaalisessa palvelussa.
- Yrityksen koko yli 100 henkilöä (N=5):
  - Mobiilisovellukset.
  - Tuotteiden digitaalinen kustomointipalvelu asiakkaalle.
Digitalisaatio vaatetus- ja tekstiilialla: - ratkaisut liiketoiminnassa

"Arviointi, mitä luettelusta digitalisaation ja uusien teknologioiden ratkaisuja tuotteet todennäköisimmin hyödynnämään yrityksen liiketoiminnassa lähitulevaisuudessa?"

- Yrityksen koko alle 10 henkilöä (N=28):
  - Asiakastiedon analyysit (ostotiedot, fokusointu markkinointi kanta-asiakkaille, ...)
  - Digitaalinen printtaus kankaalle tai vaatteelle.

- Yrityksen koko 10-100 henkilöä (N=22):
  - Asiakastiedon analyysit (ostotiedot, fokusointu markkinointi kanta-asiakkaille, ...)
  - Asiakkaiden onlinekäyttäytymisen analyysi (esim. web-sivuilla vietetty aika ja asiakkaiden tekemät tuotteiden tarkastelut).

- Yrityksen koko yli 100 henkilöä (N=5):
  - Digitalisaatio varastoinnissa tai logistiikassa.
  - 3D-kaavoinnit ja -mallinnus suunnittelussa
Lyhyesti

- Digitalisaation hyödyntäminen vaatetus- ja tekstiilikalalla on käynnissä:
  - Hyödyntäminen on pidemmällä isommissa yrityksissä.
  - Tällä hetkellä digitalisaation näkyy erilaisten sosiaalisen median kanavoiden, verkkokaupan ja web-mainonnan hyödyntämisessä.
  - Digitalisaation hyödyntäminen tulee selvästi kasvamaan lähimmän kolmen vuoden aikana.

- Suurimmat haasteet liittyvät resursseihin (sekä taloudellisiin että henkilöresursseihin) ja osaamisen puutteeseen

- Digitalisaation hyödyntäminen tulee näkymään erityisesti erilaisten kustomointipalveluiden tarjonnan lisääntymisenä:
  - Kustomointipalveluiden ja asiakkaan mitatietojen hyödyntäminen korostui kaikissa vastauksissa.
  - Isommat yritykset panostavat myös omien prosessien digitalisointiin (3D-kaavoitus ja -mallinnus suunnittelussa) sekä logistiikan ja varastoinnin kehittämiseen digitalisaatiota hyödyntämällä.
  - Pienemmässä yrityksissä korostui myös kanta-asiakasjärjestelmien kehittäminen.
Lisätietoja

- Lisätietoa kyselystä, kyselyn tuloksista sekä DICI-projektista:

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