A study of why companies did not execute the plans they had during the first 3D body scanning hype, as well as an advising study to renew the attention for 3D body scanning and provoke better results.

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Image front page: Body shapes, adapted from CadModelling, 2010
Summary

On the brink of the new millennium many people and companies dreamt about using the technique of 3D body scanning in the clothing industry. A lot of the ideas were not as feasible and realistic as was thought at the time and many plans had to be abandoned. After ten years, this has disappeared to the background.

During this time many changes have occurred, concerning techniques as well as the environment in which clothing is sold. Internet shopping is taking a fly and consumers are becoming increasingly critical towards the products available to them. Meanwhile, 3D body scanners are being implemented in airport security.

This thesis aims to describe the technology of 3D body scanning, to find out on what grounds the technology was rejected and to look for opportunities to renew the attention for it. Therefore, the research question of this thesis is as follows:

Why was 3D body scanning not taken in as a technological development during the hype at the end of the 1990’s and what opportunities exist in the present time?

The 3D body scanning technology may be an innovation that changes the way clothing is produced. While the first developments in clothing production led the methods from individual production by tailors towards a production chain that mass-produced the same garments. 3D body scanning was thought to enable the production chain to change back and to become able to keep in touch with the wishes of individual consumers.

Most 3D body scanners by projecting lights or lasers onto the subject, and then recording the reflection by a camera. The 3D image is obtained by a triangulation between the projector, the point of light and the person. This way a point cloud is built up, which can be merged into a 3D digital image of the scanned person.

The use of 3D body scanning in the clothing industry can have several advantages. Software applications allow extracting body dimensions or other information from the scan, making it possible to measure consumers without physical contact. But there are other applications of the 3D body scanning equipment possible. For instance, 3D body scanners can be used for size surveys, which could help in the definition of clearer sizing systems. Another example is the use of the technique by armies or police forces, to improve the fit of uniforms and to find out what body types and sizes are most common so the stock can be bought in the right sizes.
A new technique to try on clothing, called virtual prototyping, can also be combined with a 3D body scanner very well. This might save the industry millions of production samples each year, or allow consumers use their own 3D image to virtually try on clothing in internet shops.

Although having grown far less expensive over the last ten years, 3D body scanners remain quite a big investment, while the benefits of using the technology are not always direct. In the application for producing Made-to-Measure (MTM) clothing, it is more usable as a marketing instrument rather than a solution to fasten and modernise the process of selling and producing the garments.

Apart from the financial risks, another reason to reject the technology was the complexity of the software applications to the 3D body scanners. It has proven complicated to automatically take measurements from a human body. Also, developing software to automatically produce or change patterns is challenging because the fit of a garment involves an emotional and personal side, which a computer program is not able to calculate.

A third reason concerns the lack of need for innovation in the clothing industry. Although every new technology goes through several stages in the so-called Technology Adoption Life Cycle; acceptance of innovative ideas seems almost impossible in this industry. This has to do with a conservatism that comes forth from a lack of need for change. Everything has been going well, so why change the processes? This conservatism, combined with the large percentage of people that has not grown up with automation and is not able or willing to work with it, could explain/explains the lack of interest in the 3D body scanning technology.

The future of 3D body scanning probably lies in a combining the scanning with virtual prototyping or fitting software. As said before, this technique is receiving a growing amount of attention at the moment and it has rather large advantages in several different ways. In MTM clothing, the 3D body scanners may have a future as a marketing tool. But in order for this to work, the software to operate the equipment would need to be simplified to improve its accessibility.
Preface

By writing this preface, the moment has come at which I bring my graduation thesis to a close. Together with the accompanying presentation this thesis will be the end product of my education Fashion Management at the Amsterdam Fashion Institute.

With help of my supervisor at AMFI, Mr. Jordaan, the subject of my thesis came forth from my internship at the research institute TNO. I did this internship under the supervision of Prof. Dr. Daanen, who brought the 3D body scanning technology to my attention and shared his enthusiasm for the technology with me.

I have experienced these last three months as a very valuable period in which I was able to go looking for aspects of the clothing industry that attract and inspire me personally. Although this is the end of a process that at some times was difficult and somewhat stressful, at other times I have really enjoyed it. Especially the conversations with experts from various companies have been very informative and pleasant. For this, I would like to thank Ms. Adami and Mr. Franceschi, from CadModelling, Mr. Dijkstra, from Hout-Brox, Ms. Van den Hurk, from Lectra, Ms. Marien, from Gerber and Mr. Walters, from the Brova Group.

I would further like to thank several teachers from AMFI who shared their thoughts on this subject with me; Ms. Van Gerven, Ms. Kuijpers and Mr. Van Ruiten. And finally, my parents, Hein en Yvonne, my partner, Geert, and my friend Henriëtte for supporting me and for reading and correcting my work.

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Introduction

Towards the end of the 20th century 3D body scanning became quite a hype. The scanning equipment had not been commercially available before. The technique became widely known, which led to aspiring dreams and ideas about what new possibilities it could bring the clothing and fashion industries. During this hype a lot has been written about applications in anthropometric measuring, internet commerce and tailor-made clothing. However, ten years later many of those plans seem to have been abandoned and a lot of dreams have been forgotten. Most of the companies that wanted to try to implement a 3D body scanner never got to it. Some of the ones that did try went bankrupt.

It remains to be seen if the applications described at that time can be considered realistic. Even now, not all of those uses are possible yet. Nevertheless, organisations that sell corporate wear or tailor-made clothing may benefit from using the 3D body scanning technique instead of taking measurements by hand. And as internet shopping is becoming increasingly important and consumers demand personalisation and quality, we might be more ready than before for 3D body scanning.

But why was the technique not taken in during the hype? And what could be done to make 3D body scanning more desirable?

A possible objection against using 3D scanners in the consumer market is that it was not achievable to scan through clothing. Therefore, a person who wished to be scanned had to undress, at least down to his underwear, so that his true body dimensions could be measured. This could be seen as a nuisance or as a violation of privacy. New developments in scanners used for security on airports may offer a solution for this.

Also, other arguments against 3D scanning that existed ten years ago, might nowadays prove to be less problematic. An example of this is the price of 3D body scanners. The scanning technology has become a lot cheaper while it was further developed for better precision and more possible applications. Also, the market may have become more interested because internet retailing is a rapidly growing influence in the clothing industry. To decrease the large number of returns of online sales, the consumer needs a better way to find out how well the clothing will fit his or her body type before the item is bought and shipped. Developing a better, common EU-size system may solve this, but 3D scanning could be another option. Once the consumer has a 3D-bodyscan he may be able to upload it to an internet shop and virtually try on the clothing, or even buy made-to-measure clothing. The latter would not only increase the probability of a good fit, but also approach the consumers’ wishes to adapt products to their personal taste.

Research question

Why was 3D body scanning not taken in as a technological development during the hype at the end of the 1990’s and what opportunities exist in the present time?
Secondary research questions

- What is 3D body scanning?
- How was 3D body scanning developed through time?
- What was fantasy and what was possible at the time of the hype around 3D body scanning?
- What reasons of clothing companies existed at the time not to adopt the 3D body scanning technology?
- Do those problems still exist nowadays?
- What opportunities exist for 3D body scanning?
- What developments are required to make 3D body scanning a successful technology in the clothing industries?

Limitation

This research is meant as an independent observation and recommendation to explore if it would be beneficial for clothing companies to re-consider 3D scanning technology. In this thesis corporate wear, tailor-made clothing and mass customisation will be discussed in more detail than mass production, because they are more relevant. In corporate wear there are higher requirements of fit and sizes every year. In tailor-made clothing a 3D scanner may simplify and speed up the process of taking measurements and adjusting patterns and may increase the accuracy. In a market in which consumers get more and more opportunities in customising their products, 3D scanning may enable more personal products.

The research presented does not aim to determine if the described applications are technically possible or able to become so in the future. Also it is not meant to describe a way for a company to incorporate 3D scanning or calculating the exact feasibility of doing so. Therefore it is not meant to describe the entire path of implementing a scanner in a production chain, or to research the exact technical possibilities of 3D body scanning. However, aspects of this may be pointed out in analysing the companies’ reasons not to use the technique.

Method

The most important sources in this thesis are literature study and interviews.

The literature has mainly been used to get an insight into the developments of 3D body scanning during the last few years. The accent lies on popular (scientific) articles. Based on articles from newspapers and magazines from around 1998, an image has been formed of what dreams and fantasies existed during the hype, and which part of these dreams was realistic at that moment.

Interviews with persons working in different areas in the production of clothing will be an important part of the research. With the help of literature study and conversations with experts, a few companies have come up that could provide a valuable insight into the reason why the technology has not taken root in the industry.
Relevance

This thesis can prove relevant to people and companies wanting to obtain a global overview of the possibilities and developments in the technology of 3D body scanning. It intends to help find a way through all the publications that only describe a small part of the whole technology and its applications. The research also suggest which applications of 3D scanning might be useful to the clothing industry.

Structure

The first chapter offers a global overview of the developments in the industrial production of clothing and is followed by chapter 2 which describes three different ways of production. Chapter 3 explains the technical aspects of 3D body scanning. It provides some insight into the way a scan is made and what companies are involved in the hardware and software applications. In the fourth chapter some of the advantages of the use of the 3D body scanners in clothing productions are described. Chapter 5 is about the investments involved with the technology. Using a 3D body scanner requires quite large investments, so what can be gained by using 3D body scanning? The sixth chapter revolves around the dreams and aspirations that have become clear from articles written during the hype. It also tries to give an idea of the (im-)possibilities of 3D body scanning. Chapter 7 describes possible reasons why companies did not use the technique, while chapter 8 describes the reasons that may help the technology to gain further influence in the future.

The research ends with an overview of the conclusions and recommendations that have come forth from literature study, interviews with experts and site-visits to relevant companies in the industry.
1 Developments in the production of clothing

In order to understand the impact on the clothing industry of possible 3D body scanning implementation, it is important to place it in the context of the development of modern production. This shows that changes in the production processes of clothing have most often been very slow and gradually. Major changes usually encountered quite some resistance, from both tailors and manufacturers, as well as from the spirit of the times.

1.1 Short history of production

Until the end of the 18th century, clothing was produced on demand. People made their own clothing or, if they could afford it, ordered a piece at a local tailor. Depending on the price you were able or willing to pay, the tailor estimated or measured your body dimensions and made you a piece of clothing that suited the fashion of your class.

Just before the start of the 19th century, certain radical changes took place in the way products were made, starting in the United Kingdom. The invention of the steam engine set off the Industrial Revolution. Soon the industrial developments also reached the mainland of Europe. This led to the first mass-production of all sorts of products, including clothing.

During the twentieth century a lot has changed in European societies. The welfare of common people has multiplied. People have more money to spend and are willing to do so as well. Also, the average level of education has become higher. Because of these developments, consumers have
started to demand more of products in terms of quality and how well they match their expectations. Another effect of the expanding welfare is that consumer demand is getting more divergent because of growing individualism in societies. In the clothing industries, especially in fashion, the progressive welfare thus leads to extended heterogeneity and unpredictable consumer demand. Producers react to this by expanding their product range with numerous variations. However, this does not always lead to a higher satisfaction of the consumers’ needs. Figure 3 (page 19) shows the process described above. (Hin e.a., 2003)

Over the last decade, suppliers changed some product lines from mass-production into mass-customisation. This enabled the industry to fulfil the consumers’ need to express their individual taste through their clothing. Customised sneakers are a good example of this. Sports brands such as Nike (NIKEiD), Adidas (Mi Adidas) and Puma (Mongolian Shoe BBQ) allow customers to choose style, colour and materials for every part of the shoes.

So what could be the next step? When the technology of 3D scanning was introduced a little over ten years ago, it seemed as if within a few years, the industry would go back from mass-production to made-to-measure or even a modern version of tailor-made clothing. But although there are some developments visible toward mass-customisation, it still is nowhere near the scale that was envisioned.

1.2 Development of sizing systems

At the beginning of industrialised production, the manufacturer decided what he wanted to produce, which he then tried to sell to customers. After some time it became clear that it might be beneficial to do some research to find out what styles and sizes were likely to be sold. Finally the first sizing systems for clothing were developed.

‘The Proportionate and Universal Table’ (Figure 4), one of the first sizing systems, was developed in 1815 by Benjamin Read. He used inches and listed ten proportionate measurements that could be used in pattern making. European tailors were the first to be interested in anatomical body measurements and proportions and their relation to clothing patterns. The first sizing systems were used in men’s clothing. Around 1850 ready-to-wear clothing became available to the greater public. At first only menswear started to become more industrialised.
Until 1910, women’s wear was still made at home or in dressmaker’s workrooms, which had mainly to do with the high standards in the tight fit of women’s clothing. In order to develop cheap ready-made clothing for women, not only expertise and methods of mass production were needed. The most important factor was a change of mind; only once it became a smarter form of dressing than wearing home-made clothing, the mass production of women’s clothing would become truly successful. Figure 5 shows an example of women’s clothing that was better suited for mass production because the garments were loose, reducing the need to follow the exact body contours, thereby simplifying the patterns.

During the second half of the twentieth century the need for sizing standards emerged in order to mass-produce ready-to-wear garments instead of mass customisation. This led to methods to measure and categorises populations. Although more knowledge on body dimensions is obtained, every brand uses it differently and there is little insight into the sizes. The sizing systems have become unclear, mainly in women’s wear. The introduction of 3D body scanning may enable a modern variant of the nineteenth-century mass customisation, thereby solving the sizing problems. (Aldrich, 2007)

“Typically an apparel company arrives at a sizing system for a product line as follows. First, it defines a target market and typical customers by identifying demographic characteristics, such as age, income, ethnicity, and lifestyle. Then the firm chooses a single person – the “fit model” – to be the idealized body shape for that product and market. Prototype garments are created, then evaluated and modified in fitting sessions in the single fit model. A base size pattern is perfected for this prototype garment, and proportional grade rules are used to scale a set of patterns up and down for the size range, e.g., 2-16. ... Proportional grade rules do not address the differences in the basic shapes and body proportions of the population or the differences across ages and target markets. A single fit model has a particular body shape that is translated to the full range of sizes. Providing good fit using a finite set of sizes for an almost infinite range of body types is a challenging task. The new information available from the 3D body scan research will help us meet this challenge.” (Cornell University, 2009)
Currently media are reporting a certain progress in the development of a common EU sizing system, governed by a commission of representatives from various European parties. Although this seems very hopeful, it remains to be seen if this commission will succeed anytime soon. The standardisation of size systems is a subject that has emerged every few years for the last decades. But for it to be truly introduced many different parties will need to make great concessions. Figure 6 shows the proposed size label that might be used to indicate the new EU-sizes. Remarkable is that the sizes take into account that people come in different body shapes. In order to provide the right sizes for every shape, the label indicates a length measurement, as well as the circumference. This resembles the NATO-size systems that are used by several international military organisations. If it is developed in a way that is easy to read and remember, this might be a great improvement in comparison with the size systems as we know them now.

*Fig. 6 Concept of a new EU-size label. (Adami and Franceschi, 2010)*

The table in Appendix I shows an overview of developments in the production of clothing.
2 Different types of production

This chapter will show the difference between a number of production methods, especially in terms of the kind of product, lead time, the way production is organised, the price of products and the amount of influence an individual consumer has on the final product. The types of production discussed in this chapter do not give a complete overview of all possibilities but instead focuses on a few methods to show the relevant differences.

2.1 Mass Production

As mass production became a more common way of producing, manufacturers started to specialise in specific product types. This way the number of different specialised machines and skills of workers remained limited. Mostly basic products such as T-shirts, underwear and socks are being produced in mass production because these products have a low fashion risk. There will always be a demand for these products and therefore they can remain in stores longer than most other goods. (Burns and Bryant, 2007) Sometimes the products are not even produced in their final colour. This is done at the last possible moment, when the seasonal colours are known. (ecommons, 2010) Mass production is able to provide a very large market, albeit a homogeneous one. (Lee and Chen, 1999)

At first, in the apparel industry mass production was a process that took 66 weeks. Figure 7 shows the difference in production time between mass production and mass customisation. (ecommons, 2010)

![Mass Customization Time Frame](image)

*Fig. 7 Production time frame.*

Table 1, page 24, shows some distinct characteristics of mass production, as well as (dis-) advantages of this way of producing.
<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production org.</td>
<td>Specialised production</td>
<td>Workers can carry out the repetitive tasks with great speed and dexterity. (Hughes, 2010)</td>
<td>Boredom sets in as the job is monotonous and recurring. (Hughes, 2010)</td>
</tr>
<tr>
<td></td>
<td>Division of labour</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very large quantities</td>
<td>Low cost-price</td>
<td>Large finished goods inventories → High costs and risk of markdowns and/or unsold goods (ecommons, 2010)</td>
</tr>
<tr>
<td>Price</td>
<td>Very low cost-price</td>
<td>The selling-price can be relatively low too</td>
<td>Relatively low quality (of fit, production and/or fabric)</td>
</tr>
<tr>
<td>Product</td>
<td>Low fashion risk products</td>
<td>Lead time can be longer</td>
<td>Standard look, lack of uniqueness.</td>
</tr>
<tr>
<td>Lead time</td>
<td>Long lead time</td>
<td>Production can be sourced globally → lower labour costs. (Burns and Bryant, 2007)</td>
<td></td>
</tr>
<tr>
<td>Consumer influence</td>
<td>No influence</td>
<td>Production in large quantities, economy of scale.</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1: Characteristics of Mass Production.*

### 2.2 Mass Customisation

Mass customisation can be seen as a hybrid of mass production and customisation (Figure 8). This system, like mass production, serves a large market with low cost products. By applying additional technology, the manufacturer is able to respond to consumer drives for custom garments. This concept of mass customisation is defined by Pine in 1993, and shown in the figure in Appendix I. (Lee and Chen, 1999)

*Fig. 8 Mass customisation (Provenmodels, 2005-2010)*

In order to implement mass customisations, it is necessary to implement technologies such as a flexible manufacturing system, computer-integrated manufacturing, computer-aided design or advanced computer technology. Mass customisation would lead to consumers having “access to a variety of relatively low-cost, high-quality, customised products while manufacturers can reduce excess inventory and mark-downs.” Mass customisation production is “Fragmented and heterogeneous” (Lee and Chen, 1999, p.2)

Although this system seems to require great investments, most modern manufacturers do not even need to make radical changes, because they are usually already applying digital ways of communication. The most important adjustment is to add an extra production line that produces the
on-demand products. A transport system that uses tables or carts would not be efficient, because it would be impossible to clearly separate different orders. A hanging transport system would be better, because it prevents different orders from getting confused. (Van Ruiten, 2010)

Production based on ‘Push’ or ‘Pull’

Fig. 9 Traditional versus future organisation of the production chain.

Fig. 10 Possible effects of mass customisation in the apparel industry.

Figure 10 shows a model of the effects of mass customisation in the apparel industry by Anderson et al. (1997) “Based on consumer research, they indicated that digital information and new technology in the process of manufacturing will develop customised apparel with four options:

* In the ‘design option’, ... the customer selects from manufacturers/retailer’s designs, sizing, style options, style details, colour, and fabric to create the designed garment, through computer aided design (CAD) and digital printing.

* ‘Co-design’ offers additional personal fit through a design manager, based on the design option choices.

* Finally, in ‘total custom’ the customer communicates his or her own designs to manufacturers or retailers in a digital format.” (Lee and Chen, 1999 p. 4)
The term mass customisation is used for many different forms of production. Below, two distinctions are set out that are often ignored in practice.

Mass production with variety
Zipkin (2001) distinguishes mass customisation and mass production with variety: Mass customisation differs from mass production with variety because: “Instead of selecting one variety of a product (mass production with variety), each customer provides unique information so that the product can be tailor-made to his or her requirements (mass customisation). The production process must be very flexible in order to meet those requirements.”

Mass individualisation
Another distinction is based on the different moment the consumer starts to participate in the process. In mass customisation the consumer can only influence the final assembly, distribution and presentation, whereas in mass individualisation, the consumer initiates the entire production of his desired product. (Hine et al., 2003)

Table 2 shows some distinct characteristics of mass customisation, as well as (dis-)advantages of this way of producing.

<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production org.</td>
<td>Production on demand</td>
<td>No finished goods inventory</td>
<td>Consumers have to wait</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Zipkin, 2001)</td>
<td>(Zipkin, 2001)</td>
</tr>
<tr>
<td></td>
<td>Delivery directly to customer possible</td>
<td>Quick and focussed delivery, no unnecessary transport or inventory</td>
<td>The consumer is very aware of the lead time, which therefore has to be as short as possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ecommons, 2010)</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>Relatively low cost-price</td>
<td>High margins, the selling-price can be relatively high</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Relatively high selling price</td>
<td>Relatively high quality</td>
<td>Limited demand</td>
</tr>
<tr>
<td>Product</td>
<td>Usually products with limited variable attributes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead time</td>
<td>Short (in customer’s point of view it’s quite long)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumer influence</td>
<td>The consumer can choose variations for a limited number of attributes.</td>
<td>Products that fit the customer’s needs.</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Characteristics of Mass Customisation

2.3 Customisation

Through the use of modern technologies it has become possible to develop a type of individual clothing different from the custom-made apparel produced by personal tailors or dressmaker from the past. Customised or tailor-made clothing allows the consumer to buy a product that can be entirely made or adjusted to his taste and type of body. The patterns of truly tailor-made clothing are made or adjusted to the Consumers needs and should have the exact right fit. Usually, when buying a tailor-made suit, the customer can choose its fabric and other details from a collection preselected by the retailer. This way the lead time will still be acceptable.
3  About 3D body scanning

3D body scanning is a technology that has existed for about 15 years. It can be used to make a digital, 3-dimensional model of a person. A predecessor was 2D scanning, which came forth from taking body measurements in photographs (Adami en Franceschi, 2010). This technology enables measuring a person in a way that does not require any physical contact. Advantages of 3D body scanning over hand measuring is that it is a lot faster, more precise and not dependent on personal errors. When the scanning equipment is combined with the right software, it can produce a realistic and reproducible image that can be used in several ways.

3.1 How it works

Although there are many different producers of 3D-scanners, which have all developed their own techniques, a few basic principles apply to most of them.

In most of the assemblies there is one (though usually more) projector that projects a point of light (laser) onto the subject. One or more cameras from slightly different angles catch the reflection of that light from a slightly different angle. This allows a triangulation between the projector, the point of light and the camera(s) (Figure 12). By measuring the distance and the angle of the light in respect to the projector and the camera, the 3D-location of the light can be calculated. (Daanen and Van de Water, 1998)

A second method uses a line of light that is projected onto the body and horizontally moved. The camera records the line as an irregular shape, because it is deformed by the body. Because the positions of the camera and the projector are known, the 3D-coordinates of the body can be calculated. (Daanen, 1995)
There are companies that work with another method, making use of radio waves (radar). Nowadays, this technique is also used by security scanners on airports. The biggest advantage of this technique is that it does not require the subject to undress. To some people a downside to scanning a clothed person, is that all clothing is that all clothing, but especially corrective underwear, has an effect on the shape of the body. Therefore it is questionable if an entirely realistic representation can be obtained of the clothed subject.

**Fig. 13 Virtual 3D image of a scanned person. (Adami and Franceschi, 2010)**

Usually, the raw data obtained by the scan needs to be cleaned up in order for the operator to see the relevant data. Some software (Solidworks/Artec) requires the operator to choose functions that clean and smooth out the scan. Other software (CadModelling) automatically does this before the scan is shown to the operator. The result is, in most cases, a 3D figure that is build up by a large cloud of points. Figure 13 shows an example of a figure constructed from data provided by the scanners and software of CadModelling. Note the pose in which the person is scanned. To assure that the scan is precise and does not have too many gaps most companies have defined one or more poses that the subject has to adopt. Main areas that are hard to get complete in a full body scan are the top of the head, the armpits, crotch, the inner side of both arms and legs and the feet.

According to Ms. Van den Hurk (2010), Sales Manager at Lectra, a scan needs to be further adjusted before it can be used in other software. Because a scan actually is a cloud of points, the surface needs to be merged and smoothened in order to be able to get precise measurements from the scan.

### 3.2 Producers of 3D scanners

There are many different producers of 2D and 3D body scanning equipment. To name a few: CadModelling (Italy), Tecmath (Germany), Vitronic (Germany), Telmat (France), Wicks & Wilson, (UK), Hamamatsu Photonics (Japan), Cyberware (USA), (TC)² (USA), Artec (USA).

Most of the producers of 3D body scanning systems have developed their own software, mainly to merge the individual data to a smooth surface and to extract data from the scan, including: Digisize (Cyberware), BL (Hamamatsu), Voxelan (Hamano), Body Measurement System ([TC]²), SYMCA (Telmat), Body Scanner (Wicks and Wilson), RAMSIS, Contour (Tecmath), and Vitronic (Vitronic). (Carrere, e.a. 2000)
3.3 Producers of 3D scanning software applications

There are other related software packages available which have not been developed by hardware manufacturers. They are usually developed by research centres, such as the ARN-SCAN software by the DLA-ARN program, DataSculpt by Laser Design, SHAPE ANALYSIS developed by Beecher Research Company, and 3DM developed by CAR (Clemson Apparel Research). (Carrere, e.a. 2000)

Lectra, Gerber Technology and Human Solutions are other examples of companies that develop software used for clothing production. As described below, these companies have very different attitudes towards the 3D scanning technology.

3.3.1 Gerber Technology

Gerber Technology is “a world leader in automated CAD/CAM and PLM solutions for the apparel and flexible materials industry”. (Gerber Technology, 2010) Gerber does not specifically aim at the market of 3D body scanning applications. According to Ms. Marien (2010), application engineer at Gerber, the company’s software is able to use data in a lot of different formats. Their software is quite accessible and can therefore also be used in combination with data from a body scan. Gerber offers AccuMark made-to-measure. This is a made-to-measure (MTM) application in which an existing pattern, including grading, is used as a basis for MTM clothing, by automatically making adjustments based on the customers’ body dimensions. These dimensions can be measured by hand, or can be extracted from a 2D or 3D body scan. An addition to AccuMark is the Pattern Wizard: “The Pattern Wizard feature offers the ability to generate patterns simultaneously to different body and fit specifications for different geographic markets.” (Gerber Technology, 2010) Ms. Marien explains that the Pattern Wizard essentially recreates the pattern, and makes it fit a new target group. It does not only create a base pattern but also provides an entire nest (a group of graded patterns for the available clothing sizes).

3.3.2 Lectra

Lectra is a “world leader in integrated technology solutions—software, CAD/CAM equipment and associated services— specifically for industries using textiles, leather, industrial fabrics and composites to manufacture their products.” (Lectra, 2010) Lectra produces software that can be applied in combination with a body scanner. FitNet, Lectra’s made-to-measure application, makes it possible to choose a garment and to give it the right fit. It seeks what pattern fits best, adjusts it to the sizes entered, by hand or extracted from a scan, and creates markers. In the basic pattern, the pattern makers have made clear what adjustments are possible. Modaris is a program for pattern development, while Diamino is used for marker making. (Ms. Van den Hurk, 2010)

Figure 14, page 30, shows the MTM process by Lectra.
Human Solutions is a “world market leader for 3D body scanning and ergonomics simulation” (Human Solutions (2), 2010). At first sight it seems like Human Solutions is, among other things, a producer of 3D body scanners. However, the scanners they offer are developed by other companies. Human Solutions is a developer of software applications that are very well suited to be uses in combination with the scanning technology. Therefore they work closely together with one or more scanner-producers and also take care of the sales and maintenance of the scanning equipment. The scanners they offer are developed by Vitronics, but according to Mr. Dijkstra of Hout-Brox (2010), Human Solutions is also responsible for the maintenance of Hout-Brox’ scanner, which was made by Tecmath.

“Human Solutions creates virtual human beings and puts them at the very hub of product development and manufacture. The dimensions, volume and definable skeleton points of human beings are precisely measured, exactly simulated and seamlessly integrated into relevant business processes. Improved, size-compatible and consequently more successful products are thus created.” (Human Solutions (2), 2010) Figure 15 shows a scanning and MTM process by Human Solutions.
4 Advantages of using a 3D body scanner

This chapter shows a few examples of the advantages 3D body scanning technology could bring to the clothing industry. One of the most obvious advantages is that of a quicker and more reliable way of taking anthropometric body measurements. However, this advantage is not discussed because it has been explained in previous chapters.

4.1 Clearer definition of clothing sizes

At the moment, the way clothing sizes are defined is generally unclear, mainly in women’s wear. According to Cornell University (2009), most size systems for ready-to-wear clothing are based on very limited information. In the United States, the last traditional anthropometric survey for apparel sizing had been done in 1941. By now, this survey is no longer accurate, nor relevant because of the modern body shapes. Figure 16 shows body scans of 3 women with very different shapes that all wear size 10 pants.

![Fig. 16 All size 10 (Cornell Body Scan Research Group, 2009)](image)

A lot of companies used to base (or base even still) their decisions about sizing on fitting sessions and feedback from customers. This is often not very accurate, because they only speak with a limited number of customers. (Van Gerven, 2010) Theoretically it could happen that one critical fitting model or loyal customer proves to be of great influence on the fit of a large part of a collection. But when the garments fit one particular person well, this does not necessarily mean it will be a good fit for the body shapes of the rest of the target group.

Because it is very expensive and time consuming to measure large numbers of people with traditional equipment, only a few anthropometric surveys were done. The introduction of 3D body scanners has offered a solution to this problem. Around the year 2000, during the hype around 3D body scanning technology, a new survey had been conducted among a representative group of people from different populations. This provided apparel companies with a chance to update their knowledge of body shapes and sizes, which they can use to their benefit in the development of new ground patterns on which to base their collections. Only several companies used his opportunity, because it was expensive to gain access to the information, while the return on the investment was not clear. (Cornel University, 2009)

The recording of the geometry of the consumers’ bodies benefits these consumers, because they do no longer need to know the exact size of their clothing. It could be a chance for the clothing industry to acknowledge the problem, to improve the fit of the clothing and to communicate the sizes in an understandable and clear way. (Hin e.a., 2003)
4.2 Environmental advantages

The implementation of 3D body scanning for MTM-production could lead to rearranging the production chain, which in turn would lead to environmental advantages. The production on demand ensures that there are less unsold products and less transport is needed, because of the decrease in returned units as well as the need of warehousing. (Hin e.a., 2003)

4.3 Advantages in the US Army

3D body scanning can be beneficial in different stages of the production chain. Figure 17 visualizes the benefits recognized during a research that was focused on the implementation of scanning technology in the US Army. However, these benefits may also be applicable to other areas of the clothing industry. The research has concluded the following advantages:

"The anticipated benefits centre on improving inventory accuracy, ease of use and faster processing of recruits (…), faster and more efficient forms scanning, and incorporating of 3D body scanner predicted sizes … These enhancements and technology integration have ensured that recruit issues were accurately and quickly recorded, thus giving DSCP Item Managers better production requirement data. This in turn has lead to more accurate wholesale-local inventory requirement predictions and allows for better management reports such as fill rate reports." (ARN, 2005)

Fig. 17 3D body scanning & Value Chain Relationships

The scanning technique is internationally used by several military organisations. The Dutch defence bought a 3D scanner about 10 years ago, and although it has not always been working because of technical and organisational complications, at the moment every new recruit is being scanned before he or she is handed the uniform. The Italian police are currently planning to scan about 900 women to improve the uniforms. A great plus in organisations like these is that they only provide a few different uniforms and they are sure of a never ending flow of people that need to be dressed.
5 Investing in 3D scanning technology

Before any company decides to invest in a technology, of course it has to be clear that it has some significant benefits. This chapter tries to give an insight into the benefits of using the 3D scanning technology, though it soon becomes clear that in a lot of applications the benefits are not very direct. For instance, the scanners are usable as a marketing tool rather than a cost-efficient solution.

5.1 Costs of buying a 3D body scanner and software

In 1996 a 3D scanning system cost between about €74.000 - €300.000. In 2000, quite early in the use of the scanning equipment, the costs varied from €30.000 for a 2D scanner to €75.000 – €190.000 for a 3D scanner. (Bosch, 2000) Now, CadModelling is able to sell a mobile 3D body scanner for €30.000.

Conversations with several different people have made it clear that to implement automated MTM production the entire package of required software would cost about €45.000.

In total a 3D scanner including MTM software can currently be bought for about €75.000.

Usually, a company that owns a 3D body scanner has a contract for maintenance with the company that sold the equipment or software. Such a contract is indicated at a sum of about €1500 for each scanner per year. (Walters, 2010)

5.2 Taking measurements of customers and fitting models

The time it takes take measurements of a person by hand varies greatly, from 5 to 50 minutes, with an average a little under 30 minutes. The result is a handful of measurements that can be used for pattern making and adjusting samples. When a 3D body scanner is used, this can be done in 5 – 10 minutes maximal with an easily accessible scanning system (some software-systems are more complicated, requiring more manual processing and therefore more time).

When a company needs to measure 10.000 people on average each year, with an hourly wage of €25 for the person taking measurements, the total wage for hand measurements would be about €125.000. When using a 3D body scanner this would be about €31.250, which is 25% of the price of measuring by hand.

Fig. 18 Basic body dimensions. (Transprism.com, 2008)
However, in most companies that sell MTM clothing it does not work this way. Usually hardly any body measurements are taken from customers. Instead, the salesman at the store ‘scans’ the customer with his eyes to estimate the ready-to-wear size. Then the customer tries on a fitting jacket to see how it fits, and all the changes that need to be made to the jacket are registered on a form. Therefore, the MTM selling company has no interest in body dimensions. The only data needed is of the places where adjustments need to be made and what has to be done. (Walters, 2010)

5.3 Ready-made clothing or customised clothing

A customised suit, made with or without the use of a 3D body scanner, can be produced by a usual production line. It would cost only a little more than a ready-to-wear suit when both suits are made of the same fabric, since it can be produced the same way. The selling price for a MTM suit can be higher than the price for ready-to-wear and when a 3D body scanner is involved, the consumer will probably be willing to pay extra on top of the MTM price. However, in practice the main gain in selling MTM clothing appears to be in the more exclusive fabrics that are offered. (Walters, 2010)

Of the average ready-to-wear clothing collection about 50% has to be sold for a discount up to 70%. (Stoffele and Vos, 2003) The customised suits may have a smaller margin, but when the production is well-organised, they should all be sold at 100% of its price. Moreover, there is no need for producing extra stock because of unpredictable demand and there is almost no extra production because of the usual percentage of rejected garments.

According to Kurt Salmon Associates’ 1997 Annual Consumer Outlook Survey, 36% of consumers are willing to pay up to 15% more for customised apparel and footwear, and will wait up to three weeks to receive their customised product. (Lee and Chen, 1999)

In 1999, Fenecon (at the time a trade organisation of producers of ready-to-wear clothing) estimated that about 25% of the consumers do not buy a specific product because it did not fit well. (Luyckx, 1999) A study on the process of a mail-order company discovered that 50% of the orders is sent back because the fit was not right. (Hin e.a., 2003)
6 (Im-)possibilities of 3D body scanning

During the last decade there has been a lot of research on the possibilities of the 3D scanning technology and new applications have been developed. However, it seems most parties that are involved do not have a clear image of exactly what is possible and what is not. Finding out where we stand has proven to be a difficult task.

6.1 Dreams and hopes during the hype

In the period roughly between 1997 and 2001 quite a hype existed around 3D body scanning; both 2D and 3D. This is apparent mainly from the great amount of attention to the subject in various media. Countless newspaper articles and numerous television stories were made, which enthusiastically told how much could be done once the scanners were commonly used.

The main subjects discussed most in various media can be divided into the following categories:

1. Size surveys
2. Size suggestion
3. Virtual fitting
4. Made-to-measure or tailor-made clothing
5. Producing your own design

6.1.1 Size surveys

By taking a representational sample of people from a certain population a clear insight into the body dimensions of this group can be obtained. This provides demographical knowledge of the population involved, for instance of weight gain or increasing height. Brands and producers can use this data to analyse relevant measurements in order to improve their assortment of sizes and make it better suitable for the target group. Also, the data can show a population’s most common body shapes, which could be used to optimise the relations between length and width in the clothing. When the fit of ready-to-wear clothes improves, this should mean that the available sizes are more able to dress as many people in the target group so less consumers will be disappointed.

Fig. 19 Taking measurements by hand (absolute astronomy, 2007)
Under the name of ‘Foresight Link’ the UK government has, together with British universities and industry, accomplished a project to measure a representative group of the British people. The aim of this project was not only to do a size survey in order to improve the overall fit of clothing, but also to see if 3D body scanners can in the future be used for virtual shopping and custom-made clothing. Another British company, Marks & Spencer (M&S), has used a system by the Computer Clothing Research Centre (CCRC) of the Nottingham Trent University to improve the fit of the clothing aided by 3D body scanner generated data. (Cookson, 1998)

In an international project called CAESAR, a vast size survey has been conducted by governments from the US, Italy and The Netherlands. For NedScan, the Dutch part of CAESAR, about 3000 people were scanned, forming a well-balanced representation of the Dutch population. The database with all measurements is interesting for producers of clothing, but also for instance for producers of cars or airplanes. In the near future a renewal of the CAESAR data might prove useful. It has been ten years and already the data does not present an entirely correct image of the measured population. For instance, Dutch people have grown taller by 1 mm every year, making the average height anno 2010 1 cm more than during the CASEAR survey. Also, during the last ten years the average weight has most likely increased as well.

CadModelling, an Italian company that produces and sells mobile 3D body scanners, has used the data from size surveys to develop a system in which a population can be divided into several different body types, using a software application called FXFit. According to Mr. Franceschi and Ms. Adami, who work for CadModelling, every population in every country can be categorised into the same body types. (Figure 20) The only differences are that one population is longer on average than the next, and that the amount in which individual body shapes occur differs per country or region. A person is categorized based on the shapes of his upper- and lower body. The predefined body shape can be scaled up or down to match the height of the scanned person. This way his body dimensions can be empirically compared to the average dimensions of a person of his height and body type. CadModelling’s core business is selling quite realistic anthropometric and ergonomical mannequins, based on the various body types. The mannequins are used in ergonomic testing, but are also very suited for sample fitting in ready-to-wear clothing production. (Adami and Franceschi, 2010)
6.1.2 Size suggestion

Another application of 3D body scanning is to suggest clothing sizes to customers. Once you have made a body scan of yourself you receive a personal card (‘Smartcard’/‘Body card’). With the information on the card suggestions can be given for the size you might need of a specific brand. Using the information on the card, the salesperson can then help you find the right sizes. Another option is to give consumers of a retail store a device with which they can scan the shelves and in turn are offered the right sizes. Garments with a wrong fit may even be omitted.

* The articles that discuss such cards do not describe actual plans or concepts; instead the ideas are more likely to be hopes or ambitions.

* The use of a system like this may not be a real solution to problems with sizes; it would only help consumers to find their size faster. However, in most cases you would still have to try on the clothing to find out if the fit is right for you.

* Determining what is the right fit and model for a specific person is a complex matter. It is not only a practical and theoretical choice, but also very dependent on the individual consumer’s preferences such as the type of clothing and the materials. Social and fashion trends also have an influence on the desired fit.

6.1.3 Virtual fitting

Fig. 21 Example of a virtual mannequin

The third application of 3D body scanning is using the scan for virtual fitting. If you have a 3D scan of your body you should be able to fit clothing on the digital copy of your body (‘DigiTwin’/‘Virtual mannequin’) in the retail store and on the internet.

Figure 21 shows an example of a mannequin in a virtual fitting room called ‘Awaseba’, developed by a Japanese company. This is however, a 2D application in which consumers can upload a photograph. (Techfresh, 2008)

* This could be a very good solution, mainly since internet sales are so important nowadays. In retail stores it would offer consumers the change of circumventing uncomfortable fitting rooms. On the internet customers would finally get the chance to see if they actually order the right size and if the model and fit is right for them. This should decrease the great amount of returns in internet sales.

* For retailers this also has advantages; in normal shops the fitting rooms would be less used, which saves them some of the usual mess and it might even reduce the amount of theft, since this often takes place in the fitting rooms. They do need to invest in one or more computers. Like said before, for internet retailers it would mean a decrease in returned items.
This system does mean that the collections have to be made into digital 3D items, which can be fitted onto a digital mannequin and would preferably move with the mannequin as it is turned around.

A different way in which virtual fitting can be used is virtual sampling. However, this is not something discussed much in articles during the hype and will be described in a different chapter.

6.1.4 Made-to-measure or tailor-made clothing

The data obtained from a 3D body scan can be used to make tailor-made clothing. The measurements from the scan is used as input in a software programme that is able to make or adjust patterns and then through an internet connection send to the single-ply cutter of the manufacturer. There the tailor-made clothing is produced like ready-to-wear clothing, but in the colour and model the consumer has selected. Once the consumer has his scan he does not even need to come to the actual store. Instead he just selects all the components at home on his computer and send it directly to the producer. (Figure 22)

Fig. 22 Automated MTM production (Burns and Bryant, 2007)

Automatically adapting the patterns has been done. Magdalene Daniels, founder of M’damme, has developed software that is able to change clothing patterns after entering someone’s body measurements in the computer. It has to be noted that, although this seems to have worked quite well, so far the company has only offered adaptable patterns of loose fitting clothing, because otherwise a good result cannot be guaranteed. (Textielvisie, 1996)

This way of rearranging the production chain (chain reversal) requires quite a few investments and further developments. First of all it is questionable to compare tailor-made clothing which was actually made by a real tailor with factory-tailor-made clothing based on the scan. When worn by a person with a very ‘normal’ body shape it will probably fit quite well. But to people with a more difficult body to dress, who will find this a very appealing solution, it can be less satisfactory since this possibly requires the expertise of a professional tailor. To have this done successfully by an automated process, sophisticated software would be needed.

6.1.5 Producing your own design

The consumers would be involved in the development of their purchases again. It might enable them to be creative and come up with their own ideas. It may even become possible to scan one of your child’s drawings, choose a dress and have the dress made in your size with the drawing printed on it.

This may be possible since there are single-ply cutters that are able to first print a design on the fabric, in the shape of the patterns, before cutting the patterns out of the fabric. This technique does not only allow a consumer to personally select the motive on the clothing, it also may be a way to cut down on the use of dyes or ink, which saves costs and pollution.
6.2 Applications of the technology

Several companies have developed software that allows taking body measurements from the scan. This software typically uses algorithms to define certain points on the human body, called landmarks. For example, the software can identify the location of the waist by defining the height where the back and sides are curved. Such landmarks then can be used to take measurements of the scanned subject. Some programmes require the operator to select the landmarks in order to measure the desired parts of the body; other programmes are able to automatically define and measure a list of dimensions and heights that were defined in advance.

As said before, the measurements taken can be used in a size-survey to define the average size of a population, or to find out what body shapes are most common among the measured people. Such a size survey could enable companies to adjust the fit of their products more precisely to their target group.

Another possibility is to use the scan or the extracted body-measurements of an individual person to suggest a clothing size or to produce made-to-measure (MTM), or even Factory-tailor-made clothing. This seemed to have been most appealing during the hype on 3D body scanning. Ideas varied from adjusting existing patterns to skipping the pattern making and making the clothing directly based on the person’s body. However, so far the abilities have not been unlimited. The scanning itself is not much of a problem, but producing the right software to work with the scans and make patterns with the scan data has proven more difficult. (Daanen, 2010)

6.3 Chain reversal

The main thing that comes to mind when thinking of ways of implementing 3D body scanning in the clothing industries, is to more easily produce tailor-made clothing, possibly even with not much higher costs than mass production clothing. These matters were also discussed extensively during the hype, a little over ten years ago. A change from mass production to factory-tailor-made clothing at large extent means reversing the production chain. The consumer then becomes the starting point instead of just the finishing point in the manufacturing process.

“When well done, chain reversal could cause great economic growth.” (Daanen, 2010) Chain reversal means switching from a ‘push’-strategy into a ‘pull’-strategy. Reversing the production chain has already been done on a big scale by, for instance, the car industry. It requires reshaping the production chain. It takes investments in materials such as scanning technology, but also in mentality and organisation and in a good relationship with the manufacturer. The retailer needs to be willing to work directly with a producer, without the interference of a wholesaler. (Van Gerven, 2010) So far, it seems this was not possible for small companies in The Netherlands. The only retailer that succeeded was a larger company, Hout-Brox.
6.3.1 From a manufacturer’s point of view

For a modern manufacturer it seems not to be too difficult to adapt to producing on demand while maintaining the common production lines. The most important issue for the manufacturer is that he needs the assurance that the demand is continuous. This is necessary to make sure that the production line is never without orders, while the retailer does not need to fear that the production is postponed to make room for bigger orders. Seasonal changes in the extent of the demand are something producers can handle by adding more seamstresses in the lines when the demand grows. However, in such a system it is not possible for the clients to just choose anything they want. The producer needs to have the required materials in stock; otherwise it could take months before the item is finished. Therefore the retailer has to compile a book in which the possibilities are displayed. The consumer can select the items he prefers from that book. (Van Ruiten, 2010)

Chain reversal may of course be interesting to producers of tailor-made clothing, such as corporate wear or men’s suits. But also higher end dresses, such as wedding dresses, and specialised professional sports wear could be products suitable for such an approach. It is realistic to assume that this way of producing is mainly feasible in exclusive segments, and not so much in the cheaper fast fashion companies such as H&M and Zara. (Van Gerven, 2010)

6.3.2 Regarding patternmaking

“While at first body dimensions were determined explicitly before starting to make the patterns, now this can be done ‘on the fly’, implicitly. Usually a base pattern with calculation rules and allowances will underlie a garment. These base patterns and rules have been the basis of clothing size systems for a long time and the scan data is fitted into this system. Depending on the garment only relevant body dimensions are measured to generate the pattern. (...) The pattern software has been on the market only for a short time. Regarding the fit very optimistic percentages are mentioned by suppliers of the software (over 90%). However, there has not been conducted any independent research to determine the quality of the fit of such made-to-measure garments.”
(translated from: Hin, 2006, p. 10)

Directly going from scan to pattern is not possible yet. The software first seeks a pattern that fits the scanned subject best. Then this pattern is adjusted to fit the person even better. Perhaps in ten years this can be done without using a predefined ready-to-wear pattern. Automatically adjusting a base pattern as well as automatically creating lay and cutting plans should be possible already. (Kuijpers, 2010)

The Dutch research institute TNO has done a pilot to test the feasibility of chain reversal of a company for men’s suits. This pilot showed that although consumers were overall very content with the concept, the final product did not meet their expectations. The consumers expected the suit to be immediately right, otherwise they would need to invest a lot more time and effort to finally receive a well fitting garment and then the greatest benefits is lost. (Hin e.a., 2003) For good patternmaking, knowledge of the contours of a person and the positions of the joints is essential! (Berlage, 1995)
7 Why 3D body scanning is not being used

At first sight, the scanning technology seems a wonderful chance for the clothing industry to automate more steps in the production of clothing in various ways. However, in the Netherlands it seems only one company has successfully implemented the scanners in their business and only a few companies have ever been interested to do so. Therefore it is apparent that the technology is not as appealing to clothing suppliers as an outsider might think.

This chapter describes some of the possible reasons for not using 3D scanning in clothing and fashion. The reasons listed are a combination of conclusions drawn from articles written during the hype and the last twelve years; objections mentioned during conversations with various professionals from the fashion and clothing industry; and interpretations by the writer of this thesis. These reasons are either business economical or have came forth from socio-cultural aspects.

7.1 Business economical reasons

With business economical reasons is meant internal reasons, that are practical, concrete objections against investing in the 3D scanning technology. This paragraph examines to what extent these reasons actually caused the companies to reject the use of 3D scanning.

7.1.1 Risks were too high

After a pilot in which the production chain of a men’s suit company was reversed, Hin e.a. (2003) stated that the concept was still in its infancy. According to their research, companies that took the plunge into made-to-measure technology were taking a high risk. The technique can, especially in the beginning, lead to many complaints or the scanning technology ends up as a marketing gimmick instead of a useful tool. On top of that, lead times need to be strictly controlled to make commercial chain reversal successful. (Hin e.a, 2003)

Ms. Thys (2007), from Lectra stated in an interview with D. Sluiter that she thinks the Dutch market is too small to earn back the investments. However, this does very much differ from company to company and Hout-Brox has already shown that it indeed is possible.

7.1.2 Complexity of software

Taking measurements from the scan turned out not to be optimal, mainly determining the position of the waist proved to be difficult for the software. This probably has to do with the algorithms that are developed to identify positions on the contours of the scanned subject. When measuring by hand is sometimes is difficult to define the exact position of the waist as well. This difficulty occurs more often when measuring men than women.
It has proven difficult to design software that automatically produces a pattern to perfectly fit a scanned person. Every new pattern has to be programmed, which can take one or two days. This may be possible for some brands and product groups, such as uniforms, which do not change very often. However, for most fashion companies the collection will be too big and change too quickly for this to be feasible. This means that scanning and automatically grading will probably not be something fast fashion brands like Zara or H&M would even consider. They would continually need to spend big amounts of money on programmers to keep their entire collection available as factory-tailor-made garments, while their customers usually just want to buy the latest fashion as cheap as possible.

Up until now no one has succeeded in going directly from a 3D body scan to a 2D pattern. First there has to be a premade pattern that can be adjusted, which means it still goes from 2D to 3D. Although it will probably take quite some time before it will be used in the clothing industry, the shoe industry has been using this technique for some time now, and it is slowly developing in ladies underwear and bathing suits. The technique originates from the technical textiles industry. It is difficult to apply in the production of clothing, because of the way the garments are designed. In pattern making a certain amount of extra space has to be added to allow the movement of the body (allowances). There is also the matter of expertise: 2D pattern cutters are usually not able to change to 3D development just like that. It requires different insight and knowledge. (Van den Hurk, 2010)

7.1.3 The overall fit of clothing may have improved or size systems became clearer

One of the first assumptions was that the scanning technology may have become less important because the industry had found a different way to solve problems in sizing, making investing in 3D scanning no longer necessary. When asked about this, various professionals reacted very differently.

* According to Ms. Kuijpers (2010), lecturer CAD-CAM at AMFI, the quality of fit still mainly depends on the segment of the products. The differences originate in the amount of attention towards prototyping. In lower segments only a few prototypes are made, while high segment products often are fitted and improved several times before production. The amount of prototyping has a direct impact on the quality of fit. Developments in 3D prototyping may have a positive effect on the future of the overall fit of clothing. Virtual prototyping is further described in paragraph 7.3.1.

* Ms. Van Gerven (2010) does not think that the fit of clothing has improved. However, she does believe brands are working on it. There is the NEN 13402 standard, based on NedScan. Brands nowadays mainly base their sizes on customer feedback, but this is not well organised. Most brands are reluctant to invest in size surveys, because they do not expect to see direct results from such an investment. Still, the data would be very valuable.
Ms. Van den Hurk (2010), from Lectra, thinks fashion companies pay more attention to the fit of their clothing than before. According to her it is becoming a way to compete, even for fast fashion companies.

7.1.4 Advantages were not big enough
The last decades clothing production has moved towards foreign countries and product development is more often than not outsourced. Chain reversal would mean that at least a part of the production may need to return to the country where the head office is based. It is not probable that organisations would be willing to do so. They usually are quite happy the way it is now, even though lead times have increased. Another argument to go on with outsourcing is that the technical knowledge is not much present in western countries anymore, so it would be hard to find the right people to bring product development back into the head office of companies. (Kuijpers, 2010) Still, according to Ms. Van den Hurk (2010), companies that are keen on high quality actually are taking back parts of the production back in their own hands. For instance, the process of making the patterns and cutting the fabric appears to be returning to designers or product developers at the companies’ headquarters.

As shown in Chapter 5, the price of 3D-scanners has seen a significant decrease in the last decade, which has decreased the former risk quite a lot. However, when used for producing MTM clothing the financial advantage is not very clear. And when only being used to scan a fitting model for virtual sampling, there are cheaper alternatives available. The software for virtual sampling allows the user to adjust the pre-made avatar in the programs in great detail, so a fitting model could be measured carefully and then duplicated in the avatar very precisely.

7.2 Socio-cultural objections
Other reasons not to invest in the technology of 3D body scanning may be less deliberate and personal rather than practical. They may come forth from the way the clothing industries, or even people in general, cope with innovations and change.

7.2.1 Technical innovation acceptation
The acceptation of all trends, including technical innovations, follows a certain adoption curve. In 1999, Geoffrey Moore first described the Technology Adoption Life Cycle (‘TALC’) as part of his Chasm theory. (Figure 24, page 44) It describes the several life cycles of a new technology after it has been introduced to the market. It recognizes several moments and groups of people, based on the degree in which they adopt the technology. ‘The Chasm’ stands for the period between the ‘Early Market’ and the ‘Bowling Alley’. At this time the market does not seem to develop anymore. The duration of this moment depends on the level of discontinuity. (Project Architects, 2006)
Fig. 24 Technology Adoption Life Cycle.

“Moore argued that there is a gap that exists between the early adopters of any technology and the mass market. He explained that many technologies initially get pulled into the market by enthusiasts, but later fail to get wider adoption. So to create a company that is worth hundreds of millions of dollars, entrepreneurs need to come up with strategies that will help them build a bridge across that gap.” (Alex Iskold, 2007)

The theory above gives an idea of how innovations are being taken in by a population in general. In Figure 25 the decision process within a company is further described.

Fig. 25 Innovation barriers. (Uniform Code Council)

Adoption barriers

- Lack of compelling reason
- Magnitude of effort
- Cost/benefit justification
- Risk

Management vision and commitment

Yes

- Entrenched business practices
- Lack of internal resources
- Lack of trading partner cooperation
- Successful implementation

Implementation barriers
7.2.2 Clothing industries are not used to investing in innovation

Many professionals in the clothing industry see this industry as quite conservative. Although fashion and creative aspects change very often, companies are always looking for new ideas. But when it comes to the production process not many drastic changes have been made in the last decades. They do not seem to feel any pressure to renew their production processes. According to Van Gerven (2010) business has been going so well, that it was not necessary to question the methods that were used.

A company really needs to see big advantages before investing in such a technology, especially during a time of economic recession. Still, in the end virtual prototyping is starting to become accepted, which too has taken quite some time. Several 3D applications have been available for a while now, but implementing it takes a lot of money. In these developments it is very important to have demand. (Kuijpers, 2010) Up till now, it seems a lot of companies do not pay close attention to developments in this area, and clothing companies do not seem to feel the need to change their development process.

All of the professionals asked during the research leading to this thesis shared the opinion that the clothing industry is a conservative industry. Some think that the clothing companies do not get pushed hard enough to be worried about their lack of innovation. Usually, customers keep coming and everything goes alright as it is. However, Ms. Van den Hurk (2010) thinks that the economic recession might have triggered a new movement. According to her, companies have a growing interest in optimising the production process and the technical knowledge of the employees.

7.2.3 We are just not there yet

![Image](image.png)

*Fig. 26 National Technology Scan in the US. (Parks Associates, 2008)*

There is still a large percentage of the population that has not grown up with computers and this level of automation (Figure 26). It may be something that has to ‘grow’ into the society to become more accepted and more easily implemented. (Van Gerven, 2010) This may not only apply to consumers, but to decision makers in companies as well.
The method of reversing a production chain will need to be researched and described carefully in order to reach the right level of quality. In the clothing industries a process like this takes about a year and a half. (Hin e.a., 2003) Prof. Dr. Daanen (2010), research scientist at TNO, and Ms. Van Gerven (2010), lecturer at AMFI, both believe that 3D scanning will become accepted and used in the long term.

7.2.4 Could the hype be part of the internet bubble

"The dot-com bubble was a stock market bubble which popped to near-devastating effect in 2001. It was powered by the rise of Internet sites and the tech industry in general (....) Several factors combined to cause the dot-com bubble, which is usually defined as the period of investment and speculation in Internet firms which occurred between 1995 and 2001. The year 1995 marked the beginning of a major jump in growth of Internet users, who were seen by companies as potential consumers. As a result, numerous Internet start-ups were birthed in the mid to late 1990s. ... Many of these companies engaged in unusual and daring business practices with the hopes of dominating the market. ... The American stock market rose dramatically during the dot-com bubble, with hundreds of companies being founded weekly.... Unfortunately for many companies and investors, the growth of the tech sector proved to be illusory.” (Smith, 2010)

During the dot-com bubble, there was a blind optimism towards technical innovation. However, it is not sure how much influence this has had on the development of the 3D scanning technology. In 1995, very early in the dot-com bubble, Ing. C.W.Berlage (1995), teacher at the then Institute for Fashion management & Design Koetsier (now AMFI), reported on the emerging of 3D body scanning and the technologies it derived from. Of course, it seems more than likely that the focus on technical innovations during the dot-com bubble caused 3D body scanning to become rapidly widely known.

Prof. Dr. Daanen (2010) has been one of the most prominent Dutch experts interviewed during the hype: “At that time I firmly believed in this trend on the long term and since TNO was buying the technique we also wanted to promote it in the media to make it known in the Netherlands.”
8 The future of 3D body scanning

After all those years the technology of 3D body scanning is still not as easily accessible as one might hope. Nevertheless, a number of people and companies feel / believe it will eventually be adopted by the clothing industry, though the ways in which they expect the technology to be used are very different indeed. This chapter attempts to give an overview of different factors that could help the innovative 3D body scanning to become successful.

8.1 The kind of companies that succeeded in using the 3D body scanner

As said before, in The Netherlands hardly any companies tried to implement 3D scanning in the process of selling or producing clothing, and even less did so successfully. This paragraph is meant to compare 2 Dutch companies, Hout-Brox and Possen.com. These two companies do have the scanning technology in common, but apart from that they are hardly comparable. However, this may very well be the reason for the difference in terms of success in implementing the 3D body scanner.

Fig. 27 Store lay-out of Possen.com. (Houben and Possen, 2003)

The company Possen.com was set up during the hype around 3D body scanning, and the fact that they used this technology was their unique selling point. Apart from the investment risk every new company runs in the beginning, Possen.com also invested in a 3D body scanner, which at that time cost over Fl.300.000 (estimated at about €135.000). The technique of automated MTM with body measurement from the scan and automated pattern adjustments was, and still is, not always right, so probably many suits were made that did not fit right at once. Possen.com was also called a Brick & Click concept. They did have stores the customers could visit, mainly to get scanned, but the main business took place on the internet and in a van that Possen.com used to visit companies.
Hout-Brox, on the other hand, already had many years of experience as a retail company. The 3D scanning technology can be seen as an extra service that was added later. Although it has not become entirely clear what the initial intentions were, today the technology is seen as a marketing instrument rather than a technical instrument. Hout-Brox still uses a 3D scanner in one of their retail stores (before, three out of nine stores were equipped with body scanners) but since it is difficult to find personnel with the required knowledge of tailoring, as well as the necessary interest in digital technology, two of the scanners are no longer in use.

8.2 Will the scanning technology break through anytime soon?

Whether the scanning technology will ever become a success in the clothing industry depends on a lot of different factors. One of those factors, price, is slowly but steadily becoming less of an issue. As shown before, prices have dropped since the first generation of 3D scanners. A second important problem is the matter of accessibility of the technology. (Walters, 2010) A lot of the scanners and the accompanying software are still rather difficult to use. However, new systems are being developed that are able to automatically execute the most important steps in the process to get a usable scan and to extract measurements from the acquired data.

Mr. Walters (2010), manager Made-to-Measure at the Brova Group (Hout-Brox), feels that MTM may not be the best application of the scanning technology, unless it is used as a marketing instrument rather than a way to improve measurements and fit. The real chance of acceptance probably lies in the area of virtual fitting, which at the moment is gaining in reputation and use.

Prof. Dr. Daanen (2010) sees few signs that this will happen shortly, but expects chances might improve once the economic recovers. Ms. Van den Hurk of Lectra, on the other hand, does claim to see signs that the technology is getting renewed attention. Ms. Adami and Mr. Francesci (2010), CadModelling, go even further, claiming that within five years fitting rooms will be changed into scan-booths.
8.3 What could initiate a new impulse

In this paragraph some of the possible reasons for renewed attention towards 3D scanning in clothing and fashion are described. Most of these reasons originate from the interviews with experts.

8.3.1 Growing attention for virtual prototyping

Virtual prototyping is a technique that is growing rapidly in usage. The technique has been used by shoe producers for quite some time already, but could also be very useful for a lot of modern clothing companies. By moving clothing production to the Middle East, lead times and transport costs have greatly increased. At the same time there are more collections each year, reducing the available production time greatly.

One of the organisations that already works with virtual prototyping is sports giant Adidas. They also use a 3D scanner in this process. Their fitting models have been scanned, so that the virtual fitting can be done on their virtual images, and the same is done with professional sportsmen. This way of fitting has been realised in collaboration with CAD CAM supplier Gerber and was mainly invented to cut down on the costs of sampling, and because of the growing awareness and pressure towards sustainability. Another benefit is that it shortens the lead time of the production. Virtual prototyping means far fewer samples need to be produced and shipped, often from the Middle East to Europe or the US. Adidas used to produce three million samples each year and aims to reduce the sampling costs with 25% (Kuijpers, 2010) However, a representative cannot show up with virtual samples to show their clients. At some point actual samples will have to be produced. (Van Gerven, 2010)

Virtual fitting, possibly combined with 3D body scanning, could also prove very useful in haute couture. One couture garment often needs about ten fittings for it to get the exact right fit. Therefore, when a celebrity orders a garment, high end brands often prepare two or three pieces of the same garment, so there is a higher chance that one of them is about right. If a celebrity would provide her favourite designer with a 3D body scan, the garment could be virtually fitted according to the scan, so once the celebrity is asked to try it on herself there is a good chance it will fit as desired. It is said to be expensive to import a body scan into a programme for virtual prototyping, so it may not be a feature that is easily translated to the mass consumer market. (Kuijpers, 2010)

My Virtual Model.

Fig. 29 Screenshots from MVM. (My Virtual Model, 2010)

Among other companies, H&M already has experimented with a virtual dressing room in 2006 (FashionUnited, 2006), together with My Virtual Model (2010)(MVM) who still own the website www.mvm.com. This website offers a free account to customers that want to create an outfit or shop online. Female customers can adjust a pre-made avatar to approximately
match their body type, features like skin colour, hair and eyes. The avatar can then be used to virtually match clothing and to try them on. Not all of the clothing offered at the website is available to fit onto the avatar, but those garments can be stored next to it. Most garments that are on the website are also available in internet shops that are linked to MVM. This is a good step towards an advanced way of shopping online, though virtual fitting does not guarantee that clothing will fit you well. It can give an idea of how the garments suit your body type, but mostly it serves as a virtual way to try out a new look. Figure 29, page 49, shows how an avatar can be adjusted (left), a look that is fitted on the avatar (middle), and a look that is matched aside from the avatar (right).

At the beginning, H&M was the only company working together with MVM that offered the customer the option to add personal pictures to the digital fitting model, so that she would have the customer’s face. Now this option is available to all registered users of www.mvm.com. H&M does not offer the virtual dressing room anymore.

Virtual prototyping can be interesting to fast fashion brands, because it enables shortening the lead time and cutting costs of producing and shipping samples.

8.3.2 Scanning technology in airport security
Another positive influence can be that the development of scanning equipment gets a new impulse by the growing demand by airport security companies. It can help to make the technology better known and let consumers get used to being scanned. However, the scanning in security employs a somewhat different technique of scanning, because of the differences in requirements between the use in security and the use clothing production.

The main difference is that in airport security it is very important to ensure the privacy of travellers. Therefore the software is usually developed in such a way that it only shows locations on a premade figure that need further inspection (Figure 30).

Although the software is developed to respect the person’s privacy, this still remains the biggest concern of movements against the body scanners in airport security. Unfortunately, in March 2010 a security worker at the airport of Heathrow, England, has proven those concerns not entirely invalid. He has been formally warned for harassment of a female colleague after taking a full body X-ray of her body and making a crude remark about her breasts. (AFP, 2010)

![Fig. 30 Example of an abstract figure used in airport security.](NCTb, 2010)

All in all, the developments in this application of the body scanners can have both negative and positive effects on the acceptance of the technology in other industries.
8.3.3 Growing individuality and demanding consumers
Consumers are becoming more critical towards the products they are buying. They want a good quality product for the right price, preferably with options to customise it, so it exactly fits their wishes. A good way to approach this kind of demand would be MTM-production. The scanning technology could, according to some researchers involved, improve the MTM-production chain. However, others say that it actually is only a small part of the population of consumers that wishes to customise their products.
Several professionals commented on the demand for MTM clothing:
∗ According to Ms. Marien (2010), Gerber, MTM is getting more attention in the clothing industry. Gerber reckons offering a size system with different lengths as a kind of MTM too. Ms. Marien thinks tailor-made clothing is becoming more influential as well. Gerber’s clients ask more often about these products, and the customers in the stores want to spend their money on a good product.
∗ Ms. Van den Hurk (2010), Lectra: “In several industries, including clothing, the demand for made-to-measure products is growing. People want to think they are buying a product that is exclusive, both in fit as well as in looks. Therefore, the demand for tailor-made clothing is growing as well, which is what companies such as SuitSupply are using to their advantage.”
∗ The demand in tailor-made fashion increases in specific segments. (Kuijpers, 2010)
∗ Mr. Walters (2010), Brova Group, reveals that MTM covers only a small part of the sales of Hout-Brox: It is not a core-business and should be seen as a service.

8.3.4 Growing awareness of sustainability
Sustainability may not be getting enough attention yet in the fashion industry to really have an important role in accelerating the acceptation of new ways of clothing production at this moment. But it is to be expected that this topic cannot be ignored for very long anymore. Apparently Adidas has already started using virtual sampling, assisted by a 3D scanner to scan their fitting models, in order to cut costs and to concede to the growing demand for environmental concern of organisations in the clothing industry.

Fig. 31 Growing awareness of sustainability. (Calvinscl.files.wordpress.com, 2009)

8.3.5 Developments in advanced technology in clothing
There are a lot of developments regarding the implementation of devices in clothing, such as cooling or protective vests and sensors that measure core temperature or heartbeat. These devices often need to be close to the skin and require precise fitting clothing. Scanning technology could make it easier to produce tailor-made clothing and therefore guarantee a good fit. (Daanen, 2010)
Conclusion and recommendations

After writing the chapters of this thesis, the time has come to answer the research questions that were phrased in the introduction and are repeated below.

The main research question is answered with help of the information from the previous chapters that contain the answers to the secondary questions.

The conclusions will lead to a few more concrete recommendations regarding the use of the 3D body scanning technology and other relevant enterprises.

Secondary research questions

- What is 3D body scanning? *(Chapters 3 and 4)*
- How was 3D body scanning developed through time? *(Chapter 1 and 3)*
- What was fantasy and what was possible at the time of the hype around 3D body scanning? *(Chapter 6)*
- What reasons of clothing companies existed at the time not to adopt the 3D body scanning technology? *(Chapter 7)*
- Do those problems still exist nowadays? *(Chapters 6, 7 and 8)*
- What opportunities exist for 3D body scanning? *(Chapter 8)*
- What developments are required to make 3D body scanning a successful technology in the clothing industries? *(Chapters 7 and 8)*

Research question

Why was 3D body scanning not taken in as a technological development during the hype at the end of the 1990’s and what opportunities exist in the present time?

Conclusions

The main research question will be divided into two parts, and each will be answered separately. The first part of the question wonders why the scanning technology, that seemed quite useful at first, was not perceived as such by clothing companies during the hype, a little over 10 years ago. The second part aims on future use of the technique of 3D body scanning.
1. Why did 3D Body scanning not take flight and become a new standard during the hype?

Technical complexity and utility

In the first place, the technique or 3D body scanning had some limitations at the time of the hype because the technique was complicated to use; there were limited ways to apply the scanners and the practical utility was not always as extensive as the theories suggested. To get a good result, operators needed to have knowledge of anthropometric measuring, in order to be able to identify the landmarks that were needed to take measurements from the scan. Another factor was that in a lot of cases, the software to operate the scanner itself was not that user-friendly.

Furthermore, the production of MTM clothing using automated pattern making for 3D scans proved to be difficult to achieve. Pattern making as such already is a complicated task that requires experience and good tailoring skills. Of course there are some basic rules to draw a pattern that probably can be automated. However, each garment requires its own allowances in order to obtain the right design and fit. Combined with the personal preferences of every customer regarding comfort and fit, this makes it enormously difficult to automatically produce a MTM pattern that fits exactly right at once.

Because of these limitations, the most mentioned wish to use the scanner for automatic production of MTM garments, became hard to accomplish. Some companies have tried, but with varying degrees of success. Conversations with different people in the industry have made it clear that in most cases the scanner was not a tool that made MTM clothing available to the masses. Instead of a wonderful tool to make production of MTM as easy and cheap as mass production, the scanners proved more useful as a marketing tool. The large investment needed and the high risks of investing in 3d body scanners could have easily have discouraged interested companies.

Mentality of the industry

Secondly, although the clothing industry is used to innovate in the way the garments are produced, the industry is not known for its innovation. Every technical innovation has to follow an acceptation curve in which are always decisive moments where it is unsure if the next stage of acceptation will be reached. But because the clothing industry is not open for technological changes, it will probably be even harder than in other industries.

Although most of the professionals interviewed think that the clothing industry is quite conservative, there are some that think this may be somewhat changing. Possible reasons for this are the economic recession or the higher demands in terms of sustainability. An example that was given is the recent interest of companies in virtual sampling. This technique has been available for some time now, but it seems like it is getting increasing interest.
2. What opportunities are there for 3D body scanning now?
Some things have changed regarding the reasons for not using the technology, while others still prove to be difficult to solve. The software to operate the scanners and to extract and use data from the scans appears to have developed. The systems are now able to automatically go through quite a lot of the necessary steps. Therefore operating the scanners has become more user-friendly and accessible. Possibly, the development of airport-security scanners may further stimulate software developers to simplify the process and help the technology gain a wider acceptance.

However, automatic pattern making does not seem to have made much progress yet. There are some improvements, but even now only simple patterns can be automatically adjusted and this still requires a pre-made pattern from a pattern maker. While, according to several researchers theories, it seems very useful to use the scanner for MTM production, in practice the technique makes the process more time-consuming and complicated.

A new development that can renew the popularity of the 3D scanning technique is the growing attention for virtual prototyping in companies. Together with the increasing influence of internet retailing this can lead to virtual fitting for consumers in which there might prove to be a very useful role for 3D body scanning. In order to make this successful, it would be necessary to develop several new techniques and facilities that will be further discussed in the recommendations.

Recommendations

Below some concrete ideas are described, to make the use of 3D body scanning more suitable for use in the fashion industry. Because one of the conclusions of this thesis is that the main use of the technology is not in the production of MTM clothing (yet), the recommendations focus on the use of scanners in virtual fitting. In the future, it probably will be possible to further develop MTM-applications of the 3D body scanning technology if the expertise of researchers and clothing technicians would be combined. This would however require big investments, that can prove too big for fashion companies and would need funding in a European project. Possibly the European Apparel and Textile Confederation, Euratex, could have a role in this?

Virtual prototyping and virtual fitting.

Once virtual sampling becomes more known and used, companies can also become more interested in other uses, such as a commercial application of the technique. To enable companies to start the commercial use of virtual fitting it can be interesting to start a company that offers a combination of the visualization of the garments to building or adjusting websites to enable them to support the software for virtual fitting.

It already is possible to allow customers to combine outfits on an avatar online (MVM.com), but in virtual fitting the clothing has to be visualized in a realistic way. The software also needs to take into account what the fabric would look like and how the clothing would fit around the scanned body of the customer. In order to do this those attributes of the clothing have to be documented. This should be standardized within a brand, or rather for all brands. The development of a common European size system would be of great help in this process.
Scan-booth

If the scanning technology would be an instrument for virtual fitting in online shops, the first problem is that consumers need to become able to obtain a scan easily and for a reasonable price. One way to do this is by using the example of the well-known photo-booths. This is a facility that is easily accessible. The scan-booths could be placed in areas where a lot of people can reach them. A suitable place would be a big shopping mall in big cities or in large department stores. It should be a booth with two separate rooms: one room for dressing and undressing and one that contains the scanner. It is possible to facilitate the scanner-room with footprints to show where the customer should stand, as well as handgrips, so the right posture is taken. In one of the handgrips a button can be integrated, which the customer can press to start the scanning process. This already has been done by a US company Marena, together with (TC)\(^2\), an US developer of scanners. (MarenaGroup, 2009)

The big question is who would be willing to invest in such a facility and how it can be done. Although the 3D body scanners have become far less expensive in the last decade, a scanner still costs about €30,000, and a licence of software to extract body dimensions from the scan would cost another €20,000. So, roughly estimated one scan-booth would cost about €55,000, including the entire booth and furnishing as well as a maintenance contract. In researches has been concluded that consumers would be willing to pay about €10 to get scanned. It would therefore take considerable time to earn back the investment.

Maybe a consortium of several bigger store chains that are selling online could have the funds to do something like this. For example C&A and Wehkamp, who are working together for some time now, might be interested in making such an investment. C&A has retail stores of various sizes and sells its clothing online at the website of Wehkamp, while Wehkamp may be able to interest more of the brands that sell through their website.
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### Appendix I  Table: Developments in the production of clothing

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1795</td>
<td>All clothing was made on demand by tailors or home-made</td>
</tr>
<tr>
<td>±1795</td>
<td>Industrial revolution led to the first mass-production</td>
</tr>
<tr>
<td>1810-20</td>
<td>Bernhardt makes one of the earliest records of a diagram of measurements on naked bodies used for pattern making. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1815</td>
<td>Benjamin Read publishes one of the earliest size tables. Cook and Golang devise another size system and set up a ‘School of Instruction in the Art of Cutting upon True Scientific Principles’. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1822</td>
<td>Wyatt develops a simple means of extending patterns, which is the basis of more complex modern grading systems. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1850</td>
<td>Ready-to-wear clothing began to be available to the mass of the growing urban populations. Men’s wear is becoming industrialised. (Aldrich, 2007) The first department stores were opened in Paris; new terms became in use: fixed, low prices, quality, guarantee, etc. (Berlage, 1995)</td>
</tr>
<tr>
<td>1851</td>
<td>Isaac Singer patents the sewing machine for factory use. (Burns and Bryant, 2007)</td>
</tr>
<tr>
<td>1900</td>
<td>Wholesale bespoke tailoring (mass cust.) for men becomes affordable and popular. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1910</td>
<td>Women’s wear is also starting to become more industrialised. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1914-18</td>
<td>The First World War gave a boost to the factory manufacture of clothing and was a means of obtaining large quantities of men’s body measurements. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1946</td>
<td>The International Organisation for Standardisation (ISO) was set up in response to the desire by a number of countries for international harmonisation of standards. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1951</td>
<td>The British Clothing Industry Development Council commissioned a size survey with 5000 women to improve the reliability of size systems. To reduce losses in labour and materials. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1952</td>
<td>Development of the ‘Bodygraphe’ in France, used to determine body measurements from photos. (US: ‘somatography’) (Berlage, 1995)</td>
</tr>
<tr>
<td>1963</td>
<td>The British Standards Institution (BSI) and British manufacturers come to an agreement on an imperial system of size marking: BS 3666: 1963. It marked principle body measurements that the garment should fit and tolerances for manufacturing. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1969</td>
<td>Consideration started to be given to an international sizing system for clothing. (Aldrich, 2007)</td>
</tr>
<tr>
<td>1980’s</td>
<td>Because of increasing possibilies of computers, in a lot of area’s data-acquisition systems and simulation models are developed (Hin, 2006)</td>
</tr>
<tr>
<td>1990’s</td>
<td>Digital cameras are rapidly innovated. Fast processing of digitalised 3D-images with computer vision techniques and reconstruction algorithms enable body scanning (Hin, 2006)</td>
</tr>
<tr>
<td>1991</td>
<td>Scanning technology was shown in Europe for the first time on the IBM, by CAD-Modelling (Berlage, 1995)</td>
</tr>
<tr>
<td>1995</td>
<td>Telmat shows its scanner on the CONTEC95. (Berlage, 1995)</td>
</tr>
<tr>
<td>1997</td>
<td>3D body scanning becomes a hype.</td>
</tr>
<tr>
<td>1999</td>
<td>Dutch research institute TNO and Dutch Defence buy (TC)’ scanners</td>
</tr>
<tr>
<td>2000’s</td>
<td>Software suppliers develops special modules for body scanners to make clothing patterns (Hin, 2006)</td>
</tr>
<tr>
<td>2005</td>
<td>A Standard, BS EN 13402-4 was planned for release. It designates a size coding system that would identify the primary control measurement for a particular garment, but the resistance of manufacturers has resulted in the standard being referred for further considerations. (Aldrich, 2007)</td>
</tr>
<tr>
<td>2010</td>
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</tbody>
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Appendix II  Mass Customisation Concept

Diagram:

- Mass production
  - "Large and homogeneous market"
  - Serving large market with low cost
  - Advanced Technology Application
    - Flexible Manufacturing Systems
    - Computer-Integrated Manufacturing
    - Computer-Aided Design
    - Examples in Apparel Industry:
      - Smart Card
      - Body Measurement Software & Scanner
      - Modem & Kiosks

- Mass customization
  - "Fragmented and heterogeneous market"

Flow:

Manufacturer → Mass production
  "Large and homogeneous market"
  Serving large market with low cost
  Advanced Technology Application
    Flexible Manufacturing Systems
    Computer-Integrated Manufacturing
    Computer-Aided Design
    Examples in Apparel Industry:
      Smart Card
      Body Measurement Software & Scanner
      Modem & Kiosks

Consumer Demand → Mass customization
"Fragmented and heterogeneous market"

Manufacturer
Consumer