‘Implementation of 3D Virtual Prototyping in Independent Lingerie Companies’

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The global lingerie market is growing rapidly. This has led to increased competition which forcing lingerie companies to find a way to differentiate themselves (Sorin, K 2015). The use of advanced technology in the world is increasing and the fashion industry is not staying behind (Cascio, W, Montealegre, R. 2016). 3D virtual prototyping is a technology that is being used by a lot of big fashion companies. Small companies such as independent lingerie companies are however not yet embracing this technology, which brings questions to light. The following research question is therefore analysed:

‘To what extend is it possible to both increase production efficiency and maintain quality when implementing 3D virtual prototyping into an independent lingerie company that produce hand-sewn products?’

The research question is being aswered by investigating the following topics. First the added value of the software is brought to light to see what the relevance of the implementation actually is. Secondly the costs are being researched to see if independent lingerie companies have a chance to make use of the technology which is of great value. Thirdly the perceived quality of lingerie is being assessed by professionals in the field and consumers.

This report shows that the implementation of 3D Virtual Prototyping in independent lingerie companies is a great asset to the company. Opportunities are numerous and advantages such as speeding up the time to market, reducing physical samples, lowering production costs and increasing accuracy are of great importance to implement the software.

However these advantages are only visible after implementation of 3D Virtual Prototyping and investment need to be made beforehand. A company needs to be able to provide time and money for the implementation in the beginning, which can be a struggle for a lot of independent lingerie companies. The implementation requiers gradually restructuring the organization of a company. Design and production teams need to change their way of working, which will requier guidance.

After reading this report you will be convinced that 3D Virtual Prototyping is a great asset to an independent lingerie company that produces hand-sewn pieces. The technology is already increasing in the fashion industry and will continue to do so in the future. But are independent lingerie companies strong enough to implement 3D Virtual Prototyping?
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CHAPTER 1 - INTRODUCTION

1.1 Background paper idea

The global lingerie market is growing rapidly and has shown consecutive annual growth since 2008, shown in figure 1 (Edith.com, 2013). Unexpectedly it seems that the lingerie market is a recession proof segment (Emerald, 2012). The lingerie market offers products across all different segments, with many companies targeting either the high or the low end (Parker, G. no date). As research shows, the mid-segment is however not as widely covered as the low or the high segment (Emerald, 2014). The industry offers numerous different styles, colours and fabrics in order to tailor to the needs of the consumer. Emerald et al. suggest that growing knowledge of fashion clothing has a significant role in the consumers’ confidence to make decisions (Emerald, 2014). This has led to increased competition forcing lingerie companies to find a way to differentiate themselves,

Figure 1. Growth of global lingerie market from 2008 to 2013 and estimated growth from 2013 to 2016. (Source: Edith.com, 2013)
In this research report references are made to independent lingerie companies. But what does this mean? Independent lingerie companies are called independent because of their financial state. They are not financed by large institutional investors, which makes them independent. It became apparent that the independent lingerie companies face high costs because of labour-intensive processes (Schlossberg, M, 2015). These high costs need to be recharged in the retail price. As a result their products have a high price and are not accessible for a wide audience (Sicardi, A. 2015).

Another factor is that small independent lingerie companies produce their lingerie products mostly by hand and are often shy of technology to scale up production (Van Ijken, J. 2015). Handmade lingerie is time consuming and therefore the costs are very high (Sicardi, A. 2015). Also the production of hand made lingerie is labour intensive; since every step is done by hand these lingerie companies need a lot of manpower (Lingerieaddict, 2015). Furthermore the work needs to be extremely accurate therefore they need highly trained employees. Lingerie that is not made by hand takes less time to produce in comparison to a handmade lingerie piece. Machines work faster than hands do and less steps need to be taken when using machines to produce lingerie. Hence investigating future production possibilities for small handcraft companies is more lucrative because they are often shy of modern technology.

Companies can use innovative technologies not only to innovate style but also find ways to produce more cost efficient. The use of advanced technology in the world is increasing and the fashion industry is not staying behind (Cascio, W, Montealegre, R. 2016). In order to innovate, companies need to embrace the technology offered at the moment. 3D virtual prototyping is a technology that is being used by a lot of big fashion companies such as Nike, Adidas and also big lingerie companies such as Aubade and Lisa Charmel. 3D Virtual prototyping is a software that replaces the conventional way of the prototyping phase by replacing physical prototypes by 3D

With the use of 3D virtual prototyping production costs can be lowered and by saving time in the prototyping phase, the final product can be produced faster. The efficiency of the whole production cycle will increase, which could possibly lead to more accessible exclusive lingerie products. However the luxury lingerie market is not fully implementing this technology, this could potentially reap a lot of benefits. The main reason for this is that in order to implement 3D virtual prototyping a big investment is needed, not only in money but also in time to get familiar and eloquent with the software, when looking at it short term. Larger companies have more financial strength to implement this in comparison to small companies (Schlossberg. M, 2015).

In a world where views of body image and attitudes towards beauty are changing, due to the growing presence of social media, the critical need for research seems imminent (Fisher, E. 2015). Especially in the lingerie industry, where there is a large gap between high end and low end, research needs to be conducted to meet the requirements of this changing society. Dewsnap shows for example that consumer behaviour for bras will be different from other types of apparel (Dewsnap, 2001). Insights into future possibilities, such as 3D virtual prototyping could help independent lingerie companies since production costs and time-to-market can be reduced. This reduction of production costs and time-to-market should increase production efficiency without losing quality, which could eventually result in lower retail prices, which then can lead to a more accessible luxury lingerie market for the mid-high segment consumer. This report will thus investigate to what extend it is possible to both increase production efficiency and maintain quality when implementing 3D virtual prototyping in a independent lingerie company producing hand-sewn products.
The relevance of this study applies to two parties. On one hand there is the consumer in the mid-to-high segment that loves lingerie, but is unable to buy handmade lingerie since the prices of independent lingerie are significantly higher than fast fashion brands like Victoria Secret or Hunkemoller who have a lot of financial backing to keep low production costs (Schlossberg, M. 2015). With this research handmade lingerie has the possibility to become more accessible, for a wider audience.

The other party that can profit from this research are the independent lingerie companies that produce hand-sewn lingerie, because there might be a chance that they could become more accessible and attract a wider audience, which is difficult for independent retailers since they face high cost because of the in-house production and low quantities. Furthermore there is a possibility that the production efficiency will increase, which can eventually lead to more profit and which will clear the road towards new possibilities.

The goal is to make hand-made lingerie, produced by independent lingerie companies in the Netherlands, more accessible to a wider audience by implementing 3D virtual prototyping. The goals will be accomplished when financial aspects and research show that quality can be maintained and production efficiency can be gained. The goal is reasonable since many other apparel suppliers are already implementing 3D virtual prototyping with great success towards production efficiency and quality such as Nike, Adidas, Lisa Charmel and Aubade. Currently consumers expect immediate availability and a low price tag, the lingerie market needs to fulfill these needs by providing solutions (Buis, A. 2015). Since technology is thriving and growing very fast (Cascio, W, Monteleagre, R. 2016), this will be a good field of expertise to find a solution. The luxury lingerie market has always been a detailed market that requires a lot of attention and precision. 3D virtual prototyping can possibly cater to these needs and might inspire small independent lingerie brands that produce hand sewn products.
1.4 Research question

‘To what extent is it possible to both increase production efficiency and maintain quality when implementing 3D Virtual Prototyping into an independent lingerie company that produce hand-sewn products?’.

The main research question will be answered using the following sub questions:

1. What is the added value of implementing 3D virtual prototyping?
2. What is the initial investment of the implementation of 3D virtual prototyping?
3. Which cost can be cut with the implementation of 3D virtual prototyping?
4. What is quality in the eyes of the consumer and the producer?
5. Will the quality of hand-sewn lingerie products be maintained after the implementation of 3D virtual prototyping?

What will be the concept of lingerie in this research report?

In this research report lingerie will be addressed as mentioned in the dictionary:

<table>
<thead>
<tr>
<th>Lingerie</th>
</tr>
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<tbody>
<tr>
<td>[lahn-shuh-ray, lan-shuh-ree, -juh-; French lanzhuh-ree]</td>
</tr>
<tr>
<td>noun</td>
</tr>
<tr>
<td>1. Underwear, sleepwear, and other items of intimate apparel worn by women.</td>
</tr>
</tbody>
</table>

Source: http://www.dictionary.com/browse/lingerie?s=t

To address the independent lingerie companies, the research report mainly focuses on the mid- to high segment. Prices in the mid- to high segment range from €60 to €900.
1.5 Methodology

The sub questions will be answered using different methods to gather the information needed. Below these methods are explained per sub question.

1. **What is the relevance of implementing 3D virtual prototyping?**
   For this sub question the information will be retrieved by scientific research that is done on this subject. This research can be found on numerous websites of providers of this technology, such as www.cbs.nl. Companies that use 3D virtual prototyping can give a lot of insight on this subject. The aim is to retrieve information from these companies via informal conversations and interviews.

2. **What is the initial investment of the implementation of 3D virtual prototyping?**
   This information will be gathered using websites of the numerous providers that offer this new technology. A case study will be needed to lead to additional information necessary for conceptualizing a realistic estimation.

3. **Which cost can be cut with the implementation of 3D virtual prototyping?**
   A case study of companies in the lingerie branch will give insight into the time and costs of the current process. Furthermore information can be retrieved concerning the production costs and time estimation of a future prototype for independent lingerie companies. The information will be retrieved via observation, participant interviews with professionals in this branch and the use of scientific articles. With the data retrieved from surveys and interviews a norm will be defined for the product, to confront the findings.

4&5. **What is quality in the eyes of the consumer and the producer? Will the quality of hand-sewn lingerie products be maintained after the implementation of 3D virtual prototyping?**
   This information will be relevant to see if the technology of 3D virtual prototyping can keep up with hand-made lingerie designs. To what extend is quality important in the eyes of the consumer and producer? To retrieve this information primary data such as interviews with professionals and female consumers need to be used. Additionally literature studies will help define quality in the lingerie segment. In order to retrieve this information it is important to define which consumer is interested in lower prices of handmade lingerie. This will be investigated through surveys.
1.6 Organization

The first part of the report, the theoretical analysis will begin with focussing on the added value of introducing 3D virtual prototyping in the current lingerie industry. By explaining this subject the relevance of the research will become clear. Secondly the issue of quality is assessed. What is quality in the eyes of the consumer and producer, questionnaires and interviews will show the importance of quality and this can be measured? This will lead to a better understanding of the needs that need to be maintained after the implementation. After this the current prototyping situation in independent lingerie companies that produce hand-made pieces will be sketched next to the possible prototyping situation after implementation of 3-D virtual prototyping. These situations will be divided in investment and return of investment (ROI). Also financial aspects of the costs are needed to see if it is possible to optimize the production cycle. With these subjects being discussed the pros and cons can be determined to come to a conclusion. This research will eventually give more insight on the implementation of technology in the exclusive lingerie branch. The product will be an info graphic to give a clear understanding of the report, but also a platform will be created on a website to give the option for outsourcing the technology for small independent lingerie brands that would like to implement 3-D virtual prototyping into their production cycle.

1.7 Limitations

Since the limited time and information available for this research proposal, some limitations may occur. Questionnaires and interviews only cover a small group of woman in the Netherlands, which might lead to a misrepresentation of the entire population. For example the lingerie questionnaire has been conducted on 46 women with a significant age variation. This variation is probably caused by the small power of the study participants. The conclusions of this study regarding age are thus susceptible to bias. Furthermore, other outcomes of the survey could be contradicting because of the small group, this can lead to difficulty when drawing a general conclusion. Also the interviews with independent lingerie companies only cover a small group in Holland. This is depended on the response rate of these companies, when only a few will respond this can lead to over or underestimation of the true situation in the Netherlands. And other companies maybe operate differently, which can also affect the outcome of the research. Since in the research the software provided by Lectra is being used, other software providers are left out. There is a possibility that other software providers operate differently, which means that 3D virtual prototyping in this research is only limited to the software provided by Lectra.

Researching the cost that can be cut does not provide a realistic understanding about the cost of the technology as a whole, since it might be impossible to find exact costs. This means that cost cannot be represented, which makes it hard to measure the production efficiency after implementation. Lectra offers personal packages that will differ from each company, which limits the outcome since they will be different for each company.
2.1 What is 3D virtual prototyping

The purpose of 3D virtual prototyping is to replace physical samples with virtual samples. It is possible to make use of paper patterns and produce physical prototypes or to make patterns digital and simulate them on an avatar. This last method is called 3-D virtual prototyping.

3D virtual prototyping means working with a software that develops virtual patterns. Patterns that can be digitized from a paper pattern or directly created within a CAD program. Adjustments to the patterns can be made in the CAD programme.

It is then possible to virtually sew the patterns together to create a 3D garment and simulate it on a virtual avatar. This method is called rendering; the computer estimates the exact shapes and materials (Siersema, I. 2013). Fabric properties and body measurements can be filled in the programme, this way the prototype will almost be as realistic as a physical one.

Since this process is all done digitally, changes to the pattern and therefore the fit and also to the fabric quality can be made and seen right away. The patterns can then be printed and converted in actual prototypes if needed. This method has a so-called 2D-3D-2D connection; from 2D patterns to 3D simulated prototypes and back to 2-dimensional patterns to create physical garments (Lectra, 2016).

Since timeframes are getting shorter in the fashion industry, we need solutions to speed up the time to market but still provide the highest quality possible. (Optitex Ltd. no date) With 3D virtual prototyping we can adapt to these needs.

1. Simulate: To create a representation of a model (in this research report lingerie) on an avatar.
2. Avatar: A virtual presentation of a tailormade body
3. Digitize: to convert (data) to digital form for use in a computer.
4. CAD: Computer-aided design
2.2 Advantages and disadvantages of 3D-virtual prototyping

Virtual prototyping helps with a fast development of garments, but also contributes to the accuracy of the garment (Nance, 2008). It brings the possibility to change a garment a lot faster than the conventional way, which constitutes of changing patterns and making new physical garments over and over again.

The product development cycle will be reduced, which makes the time to market\(^1\) a lot shorter (Lectra, 2016). You can swap steps that normally take a lot more time; like creating a different sample. Creating a closure on the avatar should be easy, in reality (3D) that will take a few hours of pinning and stitching. This reduced time can save money, space and resources. Saving time and resources means being more aware of the environment, which is beneficial for the sustainability of a company. Sustainability is a modern topic, which cannot be neglected. With using 3D virtual prototyping this topic can be tackled (Siersema, I, 2015). The software also opens a path to new possibilities. With the use of 3D virtual prototyping it becomes possible to show the samples digitally to the client for approval, which reduces the time to market. Additionally, digital prototypes could also be used for marketing purposes; which can be beneficial in a lot of ways.

Unfortunately the software isn’t available for everyone. Investments need to be made and education is needed in order to make use of the software (Walace, 2009). Training people how to use the programme means time investment. This means it will take up time in the beginning of the implementation, time that can be used for making prototypes for example. The initial time investment should pay off when 3D virtual prototyping is then implemented. With the implementation of the software the design team needs to be restructured, streamlined and new positions will be available. The entire organization of a company will need to change which will take great time and care (Walace, 2009).

With the use of the software there will only be 1 physical sample needed in the end. This means that there is only one moment that ‘the feel’ of the product can be assessed and fitted on a model. For the production flow this means a complete new way of the production process. The assessment of a prototype will be mainly digitally. This will take time to implement in the workflow. Also the representation of fabrics is not very accurate on the 3D simulation. It is hard to have a clear view on the fabrics used on the designs (Individuals, 2015). The avatars are not perfect yet, which is not always appealing to the eye.

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1. Time to market: Length of time taken in product development process from product idea to the finished product. It is a critical component of time based competition.
2.3 Experience and opinion of the implementation of 3D Virtual prototyping

In December 2013 Rachel Miles wrote a paper about Fashion Design and Presentation using 3D Digital Prototyping: Experiences, Opinions and Knowledge. This was part of a project called ‘Fashion 3D 3.0’ for AMFI- Amsterdam Fashion Institute.

The paper also includes the experience of the implementation of 3D virtual prototyping of Dominic Sluiter, the 3D lead of Nike Global Football and Renate Eder, Team Leader Digital Creation/Center of Excellence – Brand operation, Adidas.

The following highlights will give a clear view of the opinions and experience of the implementation of 3D virtual prototyping.

Dominic Sluiter finds the implementation of 3D virtual prototyping into the Nike workflow quiet difficult. He shares his experience by saying it is not possible to change the workflow of a design team or production team in a short time frame. The implementation needs to be done gradually with the workflow not changing radically.

For designers the implementation is not appealing at all since they are focused on aesthetics and the digital world seems complicated and unappealing for them. With the implementation they need to use more time when actually they would like to decrease their design time.

After the implementation the benefits are showing into the workflow of the designers or production team. The speed and reliability of communication between the design and production department have improved. With the 3D virtual prototyping software the production time is shorter towards the physical sample and it is easier to use the 3D designs for internal meetings and presentations.

This is one of the reasons she thinks it important to implement the 3D software into the Adidas workflow. Furthermore she finds the representation of the 3D prototypes much more convenient than the 2D sketches on illustrator. With 3D virtual prototyping there is one source with all the latest updates and information. It is easier to elaborate on a 3D model then a 2D model since it is closer to a real sample.

Internally it will have the benefit of a clear communication tool. The 3D model will have a positive influence on the presentation of the designs rather then the loose sketches all together. Misunderstanding can be rendered with the implementation of 3D virtual prototyping because of the clear presentation of the 3D model. It will also cut costs when speaking of prototypes, since they are a lot more realistic it is easier to improve and all the inaccurate prototypes are not needed anymore.

Renate Eder states the following; “you still need to improve and innovate yourself as a company, and if you don’t question the way you work today, you might not be there tomorrow”.

It’s as if I was in a computer game. Once you know the rules, you can play for hours’, explains Design student Jennifer Droguett. This virtual “game” is 3D virtual prototyping software developed by Lectra. Designing clothes with this technology can feel like playing a game with an avatar (Julia, 2014)

‘As well as being environmentally friendly, virtualisation is also innovative, quick and efficient as images are very realistic and easy to change in real time, which allows faster decision-making’. (Eder, R. 2013)
2.4 Current lingerie market

Storr, M: ‘Underwear is the most intimate form of dress, and the type of underwear known as “lingerie” is particularly invested with meanings of femininity, sexuality and pleasure’. (Storr, M. 2002)

According to Fashion Bi, the global lingerie market is booming and growing as we speak. The market is estimated to reach 24,18bn by 2017, with the mid- to high segment being the biggest part of growth.

If we look at the Dutch market we can see that bodyfashion1 (Detail, 2015) is a stable market that increases 0,6% in income every year for 3 years now as seen in figure 2.

With fast fashion being an enormous trend, the consumer is expecting to receive products fast for a small price, which means that independent lingerie companies are facing a problem.

When looking at figure 3, 53% of the woman interviewed between 19 and 61 are satisfied with the supply of the current lingerie market and the other 47% are not. The reason for satisfaction is mostly that there is enough offer or that they like consistency and are happy with a certain brand they keep using.

Most of the people that are not satisfied are missing a certain quality, which will be elaborated in chapter 3, for a lower price. Overall they think quality is not easy to find and certainly not affordable. Putting that aside they are also complaining about the offer on big sizes and feel restricted by the limited choices they have.

Social media give lingerie brands a chance to connect with their customers and find a consumer base. It is opening a lot of doors for independent lingerie brands to break into the industry (Lingerie addict, 2015).

With Social media a lot of costs can be reduced, such as finding selling points. Products now can be sold directly to the customer. The consumer can relate to a brand in an easier way, since they are no longer anonymous.

With that being said in this research proposal we mainly focus on the independent lingerie market, which sells mid-to high segment products.

Maaike Nieuwenhuis, the Dutch owner of independent lingerie brand La Maison Nouvelle, shares her opinion about the current lingerie market by saying it was old fashioned before. Nowadays the market has changed making room for new developments like the use of social media.

1. Bodyfashion: Bodyfashion stores operating in lingerie, underwear, hosiery, corsets, brassieres and the like, possibly in combination with tailoring and alteration of underwear, corsets and the like. Source: www.bodyfashion.com

figure 2. Income and income development in percentages between 2013 and 2015. This figure shows an annually growth of 0,6% in the Dutch bodyfashion sector (Source: Detail, 2015)

figure 3. Satisfaction regarding the supply of the current lingerie market. (Source: Information retrieved from questionnaire with 46 women between 19-61 (See appendix 2 + 2.1).
2.5 Partial conclusion

3D Virtual Prototyping has a lot of advantages in terms of the prototyping phase. Speed will be increased and resources are being limited and accuracy of the product will be obtained. Unfortunately these advantages need to scale up to the big investments that need to be made. Not only investment of the software which is of great value, but also the investment of time in restructuring a company and making room for new job positions.

Experiences show that the implementation of the 3D Virtual Prototyping software takes a lot of time and effort, but will pay off in the end. Especially design and production teams need to gradually change workflow. Designers will have to shift their aesthetic look to a more digital way of working, which is a big change. In the end, when being introduced with the software and trained to use it, design and production teams benefit of this new way of working.

Nowadays customers are expecting to receive products fast for a small price, since fast fashion is an enormous trend. Independent lingerie companies need to find solutions to scale up to these expectations. New technology possibilities will give them an opportunity to do so. The lingerie market is a booming market with the mid-to high segment being the most fast growing segment. Being innovative and up to speed is a must to keep growing in this market.
In the world of lingerie quality is an important factor, but how exactly can we define quality in relation to lingerie?

### 3.1 Professional point of view

Norma Loehr. Norma is the founder of Orange Lingerie and author of the bestselling book; “Demystifying Bra Fitting and Construction”. She has been sewing and designing clothes since she was nine and has been focused on custom bra- and lingerie-making since 2010. She is based in Boston. Her opinion on the quality of lingerie is very simple, it comes down to two factors: construction and materials.

When buying a lingerie piece the first thing that shows is material (Lingerieaddict, 2015). How does it look and how does it feel. There should be big differences between a bra of €20 and a bra of €200. Mid- to high segment lingerie brands search for the most beautiful materials, especially lace, satin and mesh are fabrics that define quality in Lingerie (Damen, T. no date). But elastic and closures are just as important as the main fabric of a lingerie piece (W Yu, J Fan, S-P Ng, S Harlock, 2006). The materials shouldn’t have loose threads and no signs of puckering. Natural fibres also show quality instead of synthetic fibres in the world of lingerie. The feel of fabric quality can be different for each person. It is a personal matter. That is why quality can be at a high level, but consumers have different preferences when it comes to feel, which makes it hard to decide which quality is best.

For Maaike Nieuwenhuis, owner of Dutch independent lingerie brand La Maison Nouvelle, quality of lingerie is defined by fit, comfort, sustainability and finishing. This eventually also comes down to construction and material.

The second factor construction is something that shows at second hand. Balance and mirroring are really important. Quality will be shown if a product is (visually) balanced; it should look the same on both sides. If a product is balanced and mirrored properly this means that more fabric needs to be used and more care is taken into the product, which shows quality (Loehr, N 2013).

The way in which the hems of the products are stitched is also an important factor regarding quality of construction. No raw edges should be shown and stitching should be done with special care to avoid irregularities. A product should not only look good on the outside, the inside is just as important.

### 3.2 Consumer point of view

For the consumer point of view questionnaire were send out to 45 female respondents between the age 19 and 61. Please see appendix 2 and 2.1. The question “what is quality in your eyes when speaking of lingerie” brought up a lot of different answers. To some it up the most used answers were: fit, fabric, durability, sustainability, outlook, details and comfort.

Fit and fabric where the 2 factors that were the most used when answering this question, which shows that in general professionals and consumers are on the same page when it comes to the perceived quality of lingerie.

In figure 4 the outcome of this questionnaire in relation to the question “what is quality in your eyes when speaking of lingerie” is shown. With the definite highest scores for fabric and fit, namely 40% for fit and 29% for fabric.

Figure 4. What does the consumer find most important when talking about quality in lingerie. (Source: Information retrieved from questionnaire with 46 women between 19-61 (See appendix 2 & 2.1).
3.3 What is the effect of 3D-virtual prototyping on quality?

As mentioned before 3D virtual prototyping brings accuracy to a pattern, which improves the fit of a product. With fit being one of the most important factors in the perception of quality in relation to lingerie we can safely say that this will be an asset for the industry (W Yu, J Fan, S-P Ng, S Harlock, 2006).

Since 3D virtual prototyping shows the model of a certain lingerie piece in 3D simulated on an avatar, problems can be tackled in an earlier stage. This way the fit of the product can be optimized without using a physical sample and physical fittings.

With virtual prototyping balancing and mirroring fabrics can be done easily and to top this of it could reduce the waste of fabric. Earlier on we talked about the opinion of quality of lingerie from professionals and we found out that the perfect balancing and mirroring of fabric is very important and that it shows that fabric use is very high. With virtual prototyping the quality of the balancing and mirroring of the fabric can be improved while the fabric usage can be cut down which makes the process more sustainable without losing quality.

Construction of the garments can be done fast with the use of 3D virtual prototyping, which means that creativity can flow and more options can be seen. With the possibility of trying out numerous different constructions in a small period of time, the best options can be seen right away and the product will be lifted to high quality standards. On the computer little flaws can be seen right away, which means that construction of the garment is even more important than on physical samples. With 3D virtual prototyping designers will be pushed to create to perfection.

The only quality factor that cannot be tackled by 3D virtual prototyping is the feel of the fabric in a certain piece to the body. This phase will be skipped by 3D virtual prototyping and will be saved for last. To still make sure this is being optimized, fabric test can be done to make sure this won’t be a problem in the end.

3.4 Partial conclusion

The quality, when speaking of mid- to high segment lingerie, comes down to two factors; construction and materials. Research has shown that both professionals and consumers are on the same page concerning the perceived quality of lingerie. These factors are of utmost importance when producing/buying lingerie.

The materials in the software are still in process. At the moment this quality factor cannot yet be optimized by 3D Virtual Prototyping. The materials still need to be assessed after producing a physical sample. It doesn’t mean that the fabric can be tested before this stage to tackle problems with the materials beforehand, but it will still remain a physical process.

Overall 3D Virtual Prototyping can only improve the perceived quality of lingerie. Lingerie is a very delicate form of dress, which will always be hard to perfect, since the body is very hard to generalize. The quality therefore will maintain different for every consumer.
CHAPTER 4 – COSTS

To make use of the technology of 3D virtual prototyping investments need to be made.

4.1 What investments need to be made?

The first investment that needs to be made is the investment of buying the software. Lectra will consult on the offer. Lectra makes personal packages to provide to the companies needs. These packages differ, since every company needs a different package. Unfortunately Lectra is unable to provide information about these packages.

The software is not the only investment that needs to be done. Education in using the software is another big investment that needs to be made. When implementing new software it will take time to know and understand how to use this programme. This means that a company needs to be educated.

Lectra offers education in three different stages:

1. Lectra has created the Lectra Fashion Network. This network created for Lectra users in order to exchange their experiences and opinions about the software, so Lectra as well as the consumers can develop more (Lectra, no date).

2. The second one is Fashion and Technology. This stage is offered for innovation of new business models in fashion. This platform will provide research and teaching, which gives companies the opportunity to remain innovative at all times and stay up to date about new developments within fashion and technology (Lectra, no date).

3. The last one is a training offered by Lectra for future professionals in product and design development. This serves as a way for schools, universities and companies to benefit from their expertise, best practices and latest generation tools. This training teaches them how to make use of the technology to ensure they have a good grip on processes and also push them to use their creativity (Lectra, no date).

Everything Lectra offers is focused on the future and so is their education. They make sure they make future professionals stay up to date on new developments in the world of technology and fashion and focus on new possibilities in order to stay innovative.

In order to make use of the software provided by Lectra, hardware is needed. Computers make the use of the software possible so these need to be available at all times. With the computer there are some tools that need to be available.

A digitizer will provide the option to digitize paper patterns to transfer to the computer. Digitizers can be connected to every CAD programme, which makes it possible to work on the paper patterns in the software provided by Lectra. The digitizer has different modes: mapping, streaming, drawing and tracing (Plottertrade, no date).

Plotter; to plot lines and measuring angles on a chart a plotter is needed. A plotter can graphically print patterns on paper. Since the pattern is digital a paper pattern is needed to make handmade products.

These investments are the biggest investment needed to implement 3D virtual prototyping. Without this software, hardware and education implementation is not possible. As mentioned earlier Walace (2009) argues that with the implementation of the software the design team needs to be restructured, streamlined and new positions will be available. The whole organization of a company will need to change which will take great time and care.

A solution for this big investment of the implementation could be outsourcing. A company that offers everything needed for 3D virtual prototyping and the service that comes with it. This way a lot of time and money can be saved, but the benefits will still be available for the company itself. A website will be shown as a product to visualize how this company would look and what services they need to provide in order to make this feasible.
4.2 COSTS THAT CAN BE CUT FROM THE PROTOTYPING PHASE

To measure the cost of prototyping the question ‘Which product crosses your mind first when thinking of lingerie’ is asked in the questionnaire answered by 46 women between 19-46. Shown in figure 5. We can conclude that the bra is the most common product with 75% of the answers. This means that the Bra will be the measuring product when investigating the costs that can be cut while implementing 3D virtual prototyping.

"Which product crosses your mind first when thinking of lingerie?"

figure 5. The most common perception of lingerie in products (Source: Information retrieved from questionnaire with 46 women between 19-61.) (see appendix 2 + 2.1).
4.2 COSTS THAT CAN BE CUT FROM THE PROTOTYPING PHASE

To show which costs can be cut while implementing 3D virtual prototyping table 1 is shown below to provide the information about the different steps that need to be taken with 3D virtual prototyping versus conventional prototyping.

Table 1. 3D virtual prototyping
* Note. With 3D virtual prototyping there is only 1 physical sample ideally. Only the last prototype will be produced physically. There are 2 options when using 3D virtual prototyping with only the first steps being different; Paper pattern or digital pattern.

Table 2. Conventional way of prototyping
* Note. With conventional prototyping there can be unlimited produced prototypes. The amount of prototypes depends on the state of the pattern and prototypes will be made until perfect for production.
With the implementation of 3D virtual prototyping as seen on the table 2, we can safely say that resources such as materials of the Bra are only needed at the last step. This means that with implementing the software a lot of resources can be cut, which downsizes the production cost.

Looking at the table of the conventional way of prototyping a lot of resources are needed, since physical prototypes need materials to be made. Depending on how many prototypes needed the amount of resources is needed. These resources are waste since they aren’t being used anymore after the last physical prototype is made. Prototypes are being thrown away or stacked up for reference. This means that space is needed to make the prototypes, but also to be able to store the items. Space means money and this can also be cut by implementing 3D virtual prototyping.

Alterations on the patterns and prototypes can be made on the computer with a few mouse clicks when using 3D virtual prototyping, which saves time. Valuable time can be cut, which means more can be done in a shorter time frame. The production process will be optimized which have a positive outcome on costs and manpower and lead to a shorter time to market.

4.3 Partial conclusion

The implementation of 3D Virtual Prototyping asks for investments. These investments will take time and money. A lot of steps need to be taken to implement the software in the right way. It therefore asks for a lot of care to be used in the right way. In return a lot of costs will be reduced. Resources and time will be reduced by replacing physical samples with 3D models. Time to market will be shorter and the production process will be optimized. Furthermore it will have a positive approach on the environment downsizing material and space usage.

Implementing 3D Virtual Prototyping will not only mean working with a new software, but a whole new approach on the production process will need to take place. A company needs to gradually change their organization and make investments to reap the benefits of the software, which will be worthwhile in the end. With that being said a company needs to be able to invest in time and money that needs to be made to implement 3D Virtual Prototyping.
5. SUSTAINABILITY

Emperical research has shown that sustainability is a very important ingredient of a company nowadays. Therefore the lingerie market cannot stay behind. Unfortunately there are relatively few lingerie companies that are working on this important subject (Hung, C. 2016). However there are several independent lingerie companies that recognized the importance of the subject and create lingerie, which is also good for the environment (Hung, C. 2016). Using 3D virtual prototyping will have a positive contribution to sustainability. With the reduced amount of materials, prototypes and the accuracy of the 3D simulation not only time and money is being saved but this new way of working is a sustainable approach towards the prototyping process (Siersema & Kuijpers, 2011). Looking at the garment life cycle below in figure 6. We see that implementing 3D virtual prototyping will have a positive effect on different stages; textile production, design and production. All these stages will reap a lot of benefit with this new way of working since time and resources are being reduced. The textile production will be a lot less, since there will be less physical prototypes. The design process will be completely digital which will also mean less use of material and for production we can safely say that less material is needed because of the digital way of working which will also have a positive effect on the carbon footprint of the company since there will be less movement of products/materials.

Figure 6. Garment life cycle; showing the possible life cycles of a garment. This figure shows three options. The first option (Red) is from fibre to grave, with the outcome that the garment will have no life after being used. The second option (Light green) shows the possibility of recycling/up cycling/down cycling of reusing and the last option (dark green) shows the longest option which included the garment being processed to become a fibre again which will mean an on going lifecycle of the garment.

Renate Eder, team leader digital creation at Adidas, mentioned in an article for sustainable aspect in 2013 that Adidas has saved over 1 million physical samples compared to 2010. They reduced a significant amount of money and resources, which is a positive outcome for the sustainability of the company. Also the transportation of resources decreased, meaning a reduced carbon emission.

Since independent lingerie that make hand sewn product usually produce everything in house this amount will be a lot less then a multinational company like Adidas, but still in comparison to the size of the company this will still be a positive attitude towards sustainability.
5.1 Partial conclusion

Nowadays sustainability is a very important topic that cannot be neglected. The environment needs to be handled with care and lingerie companies need to be aware of this fact and act upon it. The use of 3D Virtual Prototyping works towards a better environment with reducing the carbon footprint by less movement of materials, since materials will be reduced by the decreased production of physical samples.

At the moment there are few lingerie companies that are actively working on sustainability, but new technologies are right at their feet to increase the awareness of the environment.
The present research report provides a thorough analysis of the implementation of 3D Virtual Prototyping in Independent lingerie companies concerning production efficiency and maintaining quality.

The global lingerie market is growing rapidly. This has led to increased competition which forcing lingerie companies to find a way to differentiate themselves (Sorin, K 2015). The use of advanced technology in the world is increasing and the fashion industry is not staying behind (Cascio, W, Montealegre, R. 2016). 3D virtual prototyping is a technology that is being used by a lot of big fashion companies. Small companies such as independent lingerie companies are however not yet embracing this technology. The following research question is therefore analysed:

‘To what extend is it possible to both increase production efficiency and maintain quality when implementing 3D virtual prototyping into an independent lingerie company that produce hand-sewn products?’

Research has shown that the advantages of 3D virtual prototyping are clearly defined and up-to-date data on this matter is easy to find. Virtual prototyping helps with a fast development of garments, reducing materials but also contributes to the accuracy of the garment (Nance, 2008). It brings the possibility to change a garment a lot faster then the conventional way.

The investment needed to implement 3-D virtual prototyping covers: software, hardware and education. This results in the investment of money and time. With the implementation of the software the design team needs to be restructured, streamlined and new positions will be available. The whole organization of a company will need to change which will take great time and care. If a company is able to make this investment it will pay off eventually.

The findings on the perceived quality of lingerie were mostly similar between consumer and producer with the definite highest scores for materials and construction. This means that research has shown that both consumer and producer are on the same page about the perception of lingerie. Another finding shows that the quality in a personal matter. The power of the research on the perception of quality of lingerie is too little since it only covers a small group of Dutch consumers and producers. Outcomes could have been different if research would have covered a wider consumer and producer base. It is not possible to generalize a small group of people on this subject.

To answer the main question of this report: ‘ To what extend is it possible to both increase production efficiency and maintain quality when implementing 3D virtual prototyping into an independent lingerie company that produce hand-sewn products?’

An insignificant amount of available data has been retrieved during this research report on especially costs. This makes it impossible to answer the research question, but makes it even more relevant for further research since the generalized outcomes show a positive attitude towards the implementation of 3D virtual prototyping in independent lingerie companies that produce hand-sewn pieces. The advantages are significantly positive, but are independent lingerie companies strong enough to implement this technology? Transparancy of independent lingerie companies is needed to give an accurate answer to the main question asked in this research report.
To find out what the initial investment of the implementation of 3-D virtual prototyping will be a prospective study could give a better understanding into the costs that are made on a yearly base. The lack of data found on this subject gives a generalized and general view on the investment needed to implement 3-D virtual prototyping. With the transparency of independent lingerie companies it will become possible to find financial aspects to further investigate this topic. Independent lingerie companies that produce hand-sewn pieces will have a greater chance of existence with a positive outcome of the research question.

3D virtual prototyping is an opportunity for independent lingerie companies to become more accessible to a wider audience by lowering costs and covering the mid-segment of the lingerie market. The advantages are significantly positive and if an independent lingerie company is able to make the investment it will reap a lot of benefits making use of this software. It will bring creativity to a higher level, lower costs, increase speed to market and will open numerous possibilities.


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