VIRTUAL REALITY IN THE PRODUCT DEVELOPMENT IN THE FASHION INDUSTRY
– Application Areas, Opportunities, and Challenges of Virtual Reality in the Product Development

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Abstract

The purpose of this thesis is to examine how Virtual Reality can be applied in the product development in the fashion industry. Therefore, the research focuses on potential areas of application as well as opportunities and challenges the implementation of Virtual Reality implies.

A narrative literature review is conducted, thoroughly investigating the topic of product development and presenting the four application areas, namely Virtual Training, Virtual Prototyping, Virtual Manufacturing, and Virtual Factory, as well as identified opportunities and challenges. For the empirical part, semi-structured interviews are executed with five product developers of the fashion industry who are chosen based on a snowball sampling approach. The gathered data is evaluated using a thematic analysis.

The findings of this study indicate that the areas Virtual Prototyping and Virtual Training were perceived as relevant for the product development in the fashion industry. However, Virtual Prototyping was regarded as most important, for instance, due to the decreased need for physical prototypes resulting in time and cost reductions. Further, the research shows that there are several opportunities and challenges when implementing the Virtual Reality technology in the product development in the fashion industry.

This thesis indicates the potential of Virtual Reality in the product development for the fashion industry by showing major opportunities at different stages for the product development process. Nevertheless, there are several challenges that have to be considered in the implementation and handling of Virtual Reality.

Keywords:
Virtual Reality, product development process, fashion industry, opportunities, challenges, implementation
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<td>CAD</td>
<td>Computer-Aided Design</td>
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<td>CAM</td>
<td>Computer-Aided Manufacturing</td>
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<td>NICPPD</td>
<td>No-Interval Coherently Phased Product Development Model for Apparel</td>
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<td>PD</td>
<td>Product Development</td>
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<td>PLM</td>
<td>Product Lifecycle Management</td>
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<td>RQ</td>
<td>Research Question</td>
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1 Introduction

The first chapter introduces Virtual Reality (VR) in the product development (PD) in the fashion industry by providing some background information on the topic. The problem statement shows the research gap concerning VR in the PD in the fashion industry which leads to the clarification of this thesis’ purpose and to the research questions (RQs). A systematic procedure points out how the thesis is structured by giving a short description of each following chapter.

1.1 Background

The product development is one of the core processes in a fashion company (Nwamara, 2016) since it covers all steps needed to take the product from the design conception to the delivery of the final product to the customer (Keiser & Garner, 2012). According to Lowson, Christopher, and Peck (2004), the overall features of the fashion industry, such as short product life cycles, high volatility, low predictability, high impulse purchasing, high competition, and cost pressure, result in various opportunities and challenges for the product development. In this thesis, the fashion industry comprises the product categories defined in the McKinsey Global Fashion Index: “clothing, footwear, athletic wear, bags and luggage, watches and jewellery, and other accessories.” (Amed et al., 2018, p. 93) In order to deal with the challenges and make use of the opportunities, the implementation of computer applications can be beneficial (Burns, Mullet, & Bryant, 2016) since they can contribute to significant progress regarding fashion design and manufacturing and allow greater collaboration across supply chain partners (Papahristou & Bilalis, 2017).

VR-based systems present an upcoming technology which enable companies to interact with their environment. Further, they have positive impacts on the effectiveness and efficiency of processes (Schina, Lazoï, Lombardo, & Corallo, 2016). Therefore, investments in VR are growing (Monberg & Knauss, 2016) and revenues gained from this technology are expected to increase exponentially in the upcoming years (Jiang, 2017). According to Ferron (2016), VR has come of age with its accessibility, affordability, and quality. Monberg and Knauss (2016) point out that the technology has already been applied in several fields like education, travel, and job training and that they do not see any limitations for the future application of VR. Thus, the technology offers a number of possibilities for the fashion industry (Jiang, 2017).

Currently, Virtual Reality in the fashion industry is mainly used as a virtual shopping experience tool for the end customer. For example, the luxury brand Balmain introduced a VR tool in its store in Milan which allows the customer to experience the creative process of the brand (Bayer, 2018). But the VR technology is not only applied on the end consumer basis. Adidas, for instance, developed a virtual showroom for its B2B clients. This new showroom saves time and other resources and is going to replace Adidas’ classical showroom in the near future (Seidel, 2018).

One of the most common industrial sectors using VR in the development of new products is the automotive industry with the aim to decrease costs throughout the entire PD process, reduce time to market, enhance efficiency as well as the comfort for users. For this reason, VR is used in diverse application areas of the PD of cars, such as the design, prototyping, manufacturing, assembly, or training (Lawson, Salanitri, & Waterfield, 2016). For instance, BMW uses the VR software ‘Unreal Engine 4’ from Epic in prototyping to simulate the
design and the interior of the car, functions, engine noises, etc. and thus, creates a realistic test setting (Ashley, 2016; Stumpf, 2017). In doing so, efficient collaboration is enabled, and diverse components of the car can be tested without the need for a physical prototype (Stumpf, 2017) leading to enhanced flexibility, faster achievements, and less costs (Ashley, 2016).

However, there are some factors limiting the implementation of VR in organizations like limited budgets or the lack of experienced people. Further, since the application of VR should deliver a high quality experience, there is the need to build a large as well as diverse team in an organization (Monberg & Knauss, 2016). Nevertheless, Darrow (2018) points out that the overall opportunities of VR make it an interesting technology for many industries and departments. Due to all the above reasons, the study of the application of VR in the PD is highly topical and relevant to today’s businesses.

1.2 Problem Statement

Due to the current developments in the technology of VR, it is important to consider possible applications and to put VR on the company's radar (Ferron, 2016). In the product development process VR has proven to be beneficial to other industries, like the automotive industry (Ashley, 2016). However, as the literature shows, VR is a relatively new and unexplored topic for the fashion industry, specifically with respect to the PD. Implementing VR in this process is of interest with regard to the current challenges in the PD. Further, it is supposed to have a high potential by creating new opportunities for fashion companies.

1.3 Purpose

The purpose of this thesis is to examine how VR can be applied in the product development in the fashion industry. In this context, the research aims at investigating in which areas of PD the application of VR can be useful. Further, potential opportunities and challenges are identified when implementing Virtual Reality in the product development in the fashion industry. Therefore, this thesis intends to answer the following research questions.

*RQ 1:* Which areas of application of Virtual Reality in the product development are perceived as relevant for the fashion industry by product developers?

*RQ 2:* What are the opportunities and challenges in implementing Virtual Reality in the product development process for the fashion industry?

1.4 Systematic Procedure

This thesis encompasses six chapters that build on one another in order to find an answer to the previously stated research questions. The first chapter introduces the topic of PD in the fashion industry and establishes a link to the VR technology. Further, it states the problem, describes the purpose of the research, and defines the research questions. The second chapter provides a literature review which deals with the topic of product development in general and in the fashion industry as well as the application of VR in the product development. The literature research approach follows the structure of the thesis and starts by looking for general literature that provides information on the topics of PD and VR. Thereafter, the literature research is specified by explicitly searching for VR in the PD in the manufacturing
industry. In order to provide some structure to the search process and to facilitate finding appropriate literature, the following framework is set (see Figure 1):

Figure 1: Framework of the literature research
Source: own illustration

The third chapter gives an overview of the methodological procedure and summarizes the state of the art. Further, it guides to the empirical part of the thesis which describes the sampling, data collection, and data evaluation approach. Subsequently, the results of five semi-structured interviews are presented in the fourth chapter. The fifth chapter discusses the results and relates them to the literature. The sixth and final chapter complements the thesis by answering the research questions. Additionally, theoretical and practical implications are given, the research limitations are pointed out, and further research recommendations are provided.
2 Literature Review

In order to provide guidance for this thesis and establish an understanding of the research topic, this chapter gives an overview of current literature on PD and VR. Since the study’s focus predominantly lies on product development, the first sub-chapter thoroughly covers this topic by starting with a definition of product development and addressing several success factors. Subsequently, a model for industrial product development is illustrated and explained which forms the foundation for two further PD models for the fashion industry. The following sub-chapter deals with the opportunities and challenges in the PD in the fashion industry for which the application of VR may present a possible solution. Accordingly, the literature review continues by providing a definition of VR, leading to a detailed explanation of its application in the product development. Due to the limited available literature relating to VR in the PD in the fashion industry, this part depicts the implementation of VR in the product development of manufacturing industries in general. Furthermore, opportunities and challenges are identified and illustrated in a concluding overview.

2.1 Product Development

2.1.1 Definition and Success Factors

Golder and Mitra (2018) describe new products as the means of existence for an organization since they enable growth, enhance the economic status, and contribute to increased profits. In this context, the importance of successful product development becomes obvious supporting companies to sustain a competitive advantage and to ensure a company’s growth and corporate survival (Mu, Peng, & MacLachlan, 2009; White, 1976, cited in Goulding, 1983). The product development process seeks for innovation and can be defined as “a collection of related activities targeted to convert a new idea, concept, or market opportunity, into a marketed product.” (Karniel & Reich, 2011, p. 20) Keiser and Garner (2012) describe PD as follows:

Product development is the strategic, creative, technical, production, and distribution planning of goods having a perceived value for a well-defined consumer group; these goods are designed to reach the marketplace when consumers are ready to buy. (p. 4)

Accordingly, the development of new products includes the processes that are required to take it from the design conception to the delivery of the final product to the customer (Keiser & Garner, 2012).

The product represents an organization’s core effort taking a key role in the communication of the company with customers. Therefore, it satisfies both the company’s and the consumer’s needs which requires provision in the product development process. In this regard, the company has to ensure that the product development matches the corporate abilities and resources (Goulding, 1983). Accordingly, there is a high complexity in the product development in terms of the reciprocity of resource allocation and creativity (Cannon, 1978) as success is achieved by not only the invention of a new physical product, but the satisfaction of needs. Moreover, the product should demonstrate a newness to what consumers demand which poses a challenge for product developers (Goulding, 1983).

Cooper (2018) presents 20 critical success factors that decide if the development of new products fails or succeeds. These can be categorized in four distinct groups referring to
different levels in the product development: critical success factors at the project, the people, the business, as well as the system and methodology level (Cooper, 2018). In the following, these critical success factors are shortly described relating to the corresponding group.

Success Factors at the Project Level
The success of a product can be related to the offering of exclusive benefits and a convincing value proposition accounting for ‘unique and superior products’ that differentiate them from competitors in matters of meeting customer needs. Therefore, an awareness of what customers want, the competitive environment as well as the market itself is required to make products successful. This emphasizes a strong ‘market orientation’ and the ‘integration of the customer’s voice’ in the product development process. Additionally, Cooper (2018) mentions the completion of ‘homework’ as decisive to success, meaning the preceding steps to the actual development and design. This includes an initial market and technical assessment just as a thorough market study and business analysis. Moreover, an ‘early definition of the product’ is necessary to increase profitability and shorten time to market. The definition includes several elements such as the scope of the project, the target group, the concept of the product, product benefits, the positioning strategy, and several attributes and characteristics of the product. Furthermore, the success factors at the project level refer to ‘spiral development’ in order to deal with constantly changing information. According to that, systems and definitions have to be adaptive since external and internal circumstances change as well. With iterative steps, such as building several product prototypes, testing the different versions, getting feedback from the customer, and revising the product design respectively, market uncertainty can be reduced. The last step of a product development project concerns the product launch and marketing. This should be ‘planned thoroughly with appropriate resources and a proficient execution’ which makes it an integral part of the product development process (Cooper, 2018).

Success Factors at the People Level
Climate, leadership, and culture play an important role in a product’s success; however, they are difficult to influence and change. One key success factor to overcome this challenge relates to the effectiveness of ‘cross-functional teams’ comprising clearly defined tasks and responsibilities of team members from different departments such as Sales, Operations, and Marketing. These responsibilities are kept for the entire length of the project managed by a team leader. The sharing of information within the team further brings about an accountability for the project success. Moreover, an environment of positivity allowing innovation distinguishes successful product development from failure. This includes an ‘encouraging climate and culture’. In order to provide that ‘top management support’ is crucial by facilitating product innovations through a vision, objectives, and strategy as well as providing the required resources. A good top management should continuously empower the project teams in the product development process (Cooper, 2018).

Success Factors at the Business Level
Further distinguishing factors that decide about product development productivity relate to the business level. This postulates the establishment of a ‘strategy for product innovation and technology’ guiding the way to great performance. Such a strategy incorporates several elements like the aim and objectives of product innovation, the role it plays in pursuing the overall business goals, strategic focus areas as well as a product roadmap. Furthermore, a company needs ‘portfolio management’ to carefully choose the kind and number of projects they put effort in. A sharp focus avoids the waste of resources on poor projects which are lacking at valuable projects that need them. This prioritization can be done by means of
different criteria: fit of strategy, product advantage, market attractiveness, leverage, technical feasibility, and risk and return. Another critical success factor at the business level refers to ‘synergies with the base business’ meaning that new developed products have a strong fit between the project, resources, competences, and the company’s experience relating to various departments. These can, again, support the prioritization of projects. Additionally, new products of unfamiliar territory, such as a new product category, technology, target group, etc., increase the risk of failure as the necessary knowledge, skills, and experience are lacking. Further, an important strategic variable for new products is ‘market attractiveness’ since products on more attractive markets have a higher chance to succeed. This market attractiveness can be evaluated based on the market potential in terms of market size and growth as well as the competitive situation. Moreover, many projects fail due to a lack of financial and time-related resources. Therefore, companies need to ‘commit the required resources’ for the product development in order to guarantee project success. It also has to be considered that most companies operate on a global level today. Thus, a ‘global orientation’ and strategy for product innovation are crucial for growth and profitability (Cooper, 2018).

**Success Factors at the System and Methodology Level**

An organization’s tactical approach, procedures, systems, and techniques, and how accurately they are carried out are crucial to a successful product development process. Cooper (2018) describes five important systems and methodologies contributing to a new product’s success. Firstly, a ‘multistage, gated disciplined idea-to-launch model’, like a Stage-Gate system, can be helpful in surmounting deficits throughout the product development process (Cooper, 2012; Cooper, 2018). Many businesses use such systems for an efficient creation of new products as they provide guidance from idea to launch, enhance teamwork, detect early problems, prevent rectifications, shorten development cycle times, and thus optimize the overall success rate (Cooper, 2018). Figure 2 illustrates such a Stage-Gate system. Each stage is followed by a gate serving as a checkpoint for quality control.

![Figure 2: Example of a Stage-Gate system](image)

Source: own illustration, based on Cooper (2018)
Secondly, the integration of the ‘agile methodology from the software development into traditional gating systems’ for physical products can be a significant success factor since it enables flexibility and rapid product adaptations according to changing requirements. Thirdly, ‘effective ideation linked to open innovation’ can be critical for the development of a new product. Integrating the Voice of the Customer (VOC) plays hereby an essential role to create an effective product idea. Open innovation allows the product developers to generate knowledge or resources from external sources including “ideas for new products; [...] outsourced development work; marketing and launch resources; and even licensed products ready to sell.” (Cooper, 2018, p. 429) Fourthly, the ‘quality of execution’ of new product projects is an important factor for successful product development. Quality should be incorporated into any kind of product development tasks, from innovation to manufacturing processes. Therefore, the development team needs to be well trained and guided throughout the development process, have enough time to complete their tasks on the highest standards of quality, and get support and mentoring from the management. And lastly, ‘speed’ should be integrated into the development process in order to reduce development cycle times, be the pioneer on the market, generate profits more quickly, and achieve a competitive advantage. Nevertheless, this should be considered cautiously and speed should not be implemented to the detriment of quality of execution (Cooper, 2018).

2.1.2 Product Development Models

2.1.2.1 Process Model for Industrial New Product Development

Cooper (1983) provides a process model for industrial new product development which intends to guide managers in the development process of new products. In this context, the author emphasizes the need of the model to contain enough details and specifications for the managers. Furthermore, it must have a strong market orientation and offer support in developing a new product with a unique selling proposition in the marketplace which the customer perceives as beneficial. Moreover, the model should take a multidisciplinary perspective, strengthen internal communication among involved parties, and integrate evaluation points throughout the development process (Cooper, 1983).

The model contains seven successive stages implying different kinds of activities and each stage is detached from the precedent or subsequent one by an evaluation point which determines whether the next stage should be tackled (‘GO’) or if the development process should stop (‘NO GO’). According to Cooper (1983) the stages include: 1) Idea; 2) Preliminary Assessment; 3) Concept; 4) Development; 5) Testing; 6) Trial; and 7) Launch. Figure 3 illustrates the model, shows the seven stages as well as the corresponding activities and evaluation points.

1) Idea

Starting point of the product development process is the determination of a ‘product idea’ which develops when market requirements and technological opportunities are brought together. The corresponding evaluation point is ‘screening’ which decides upon whether the idea should take shape and become a project or whether it should be rejected. A product idea should only be taken into serious consideration when it meets the following criteria: firstly, the product idea has to be in line with the company’s guideline for new products and its mission. Secondly, the company must be able to implement the idea, have access to the required resources, or obtain them in time as well as the idea must be realizable from a technological point of view. And lastly, the attractiveness of the project needs to be assessed
with a nonfinancial approach like a scoring model, since the idea is still intangible and sufficient information are lacking (Cooper, 1983).

2) Preliminary Assessment
During the ‘preliminary assessment’ stage, information concerning the viability and the attractiveness of the project need to be gathered which implies a significant use of resources. However, the expenditure of time, labor, and costs should be kept within the limits of a predetermined ceiling. This stage is divided into the ‘preliminary market assessment’ and the ‘preliminary technical assessment’. The former aims at gaining an overview of the market, identifying potential segments, getting an idea of the market size, and anticipating the new product’s success. This activity includes the gathering of in-house information, secondary data like publicly available statistics as well as external sources such as experts from the industry. The ‘preliminary technical assessment’ estimates the technical feasibility of the product idea and the resources needed for the product development and production. The two activities are followed by a ‘preliminary evaluation’ which can contain a financial analysis even though qualitative measurement will still be the decisive factor in making the ‘GO’ or ‘NO GO’ decision (Cooper, 1983).

3) Concept
The ‘concept’ stage’s purpose is to define the product more thoroughly, its target group, and its positioning with regard to market segments and competing products. ‘Concept identification’ represents the first activity and includes a market study of potential customers. It aims at detecting a niche of consumers who are unsatisfied with the currently available products on the market, and at finding a solution on how to fill this niche to gain a competitive edge, for instance with a new technology or a distinct product design. Additionally, the market study detects how a company could gain success in the marketplace by identifying required product features and benefits, thus specifying the design according to customer preferences. The second activity, ‘concept development’, concerns the translation of the market needs into a technically practicable concept of operation. The last activity within this stage, ‘concept test’, examines whether the concept is accepted by the market. Therefore, a second market study needs to be conducted by showing “sketches, diagrams, models, or descriptions of the proposed product” (Cooper, 1983, p. 9) to a group of potential buyers. In doing so, consumers’ preferences and improvement suggestions can be considered and implemented. The two market studies do not only identify and test the product concept, but also specify the target group, the key aspects of the marketing mix, the product as well as its positioning. Hence, the marketing planning process has been started. Due to the gathered data of market acceptance and technical feasibility, estimates can be made regarding expected sales and costs, and a reliable ‘concept evaluation’ can be performed based on a financial analysis before moving on to the next stage (Cooper, 1983).

4) Development
If the concept evaluation gives the ‘GO’ for the next stage, the actual ‘product development’ can start which typically results in the creation of a prototype or sample. Besides the development of a physical product sample, a comprehensive ‘marketing plan’ needs to be developed by using the information gathered during the concept stage (Cooper, 1983). Further, a company has to decide about the supporting elements of the marketing mix, including “pricing, distribution, advertising, salesforce strategy, and service” (Cooper, 1983, p. 9).
5) Testing
Throughout the ‘testing’ stage, the product’s design features and its properties are evaluated. On the one hand, this evaluation is conducted within the firm to ensure that all technical problems are solved. On the other hand, a customer test is executed to check the design of the product and to change it upon their requests. According to the internal and customer tests, this stage is evaluated and if approved, the product reaches the ‘trial’ stage (Cooper, 1983).

6) Trial
The ‘trial’ stage implies a test run of the key aspects of the project, including the product design, manufacturing, and marketing. However, in order to start the trials, the design of the product as well as the marketing plan have to be set. The company and customer inputs from the ‘testing’ stage form the base to complete the product design, whereas the marketing plan has been running since stage three. In order to find an appropriate production method for the full range production, a ‘trial production’ is conducted. This allows changes of the final manufacturing facilities or production methods. The pilot production run further provides more precise assessments regarding manufacturing time, processing, and costs. The activity ‘test market’ aims to trial the overall marketing mix and to distribute the products according to the marketing plan to a restricted amount of customers or geographical zone. In doing so, potential adaptations of the marketing plan can be identified as well as the final assessment of market share and sales. On the basis of the financial data from the two activities, a ‘pre-commercialization business analysis’ is performed to evaluate the project (Cooper, 1983).

7) Launch
The last stage concerns the initiation of the full and final production as well as the marketing plan in the entire market area. This stage should proceed in an easy manner since all the previous stages have thoroughly tested, evaluated, and adjusted the new product. However, evaluations after the launch can be helpful in order to control the product in terms of market share, sales volume, etc. and to ensure that it is still on the right track (Cooper, 1983).

The use of this model in the product development is beneficial for diverse reasons: firstly, it emphasizes the importance of the PD to be multidisciplinary, and to consider technical and market related activities equally and concurrently. Secondly, this model promotes interaction between diverse parties involved in the PD process since all the evaluation points require feedback from different company members. Thirdly, the model helps to retain an overview of and balance the expenditures which come along with the new product project and to manage risk. And lastly, the market orientation of this model ensures that the entire development process of the new product is conform with the customer requirements. Cooper (1983) emphasizes that managers will probably not follow the model exactly according to the individual stages. Rather, since unpredictable situations or circumstances may occur, further steps should be considered and implemented. Nevertheless, the model provides normative guidance and a systematic procedure for managers to develop and introduce new products, and to overcome the numerous challenges the PD process entails (Cooper, 1983).
Figure 3: Process model for industrial new product development
Source: own illustration, based on Cooper (1983)
2.1.2.2 No-Interval Coherently Phased Product Development Model for Apparel

The previously presented model from Cooper allows process activities to occur concurrently which is also needed for the fashion product development. Since the product development process of fashion differs from the process used for other products, there is a need to apply a product development model developed for fashion products in particular (May-Plumlee & Little, 1998). Senanayake (2015) highlights that collections are developed multiple times a year which indicates that the product development process is complex and needs both close coordination and monitoring. By using a model focusing on the fashion industry, it is possible to understand critical convergent points and to identify concurrent processes (May-Plumlee & Little, 1998).

Therefore, May-Plumlee and Little (1998) developed a model for the product development of fashion products, the ‘no-interval coherently phased product development model for apparel’ (NICPPD). This model considers four departments (Marketing, Merchandising, Design and Development, and Production) coordinating and sharing the responsibility for the product development. It indicates the involvement of the departments in six phases of the product development process: 1) Line planning and research; 2) Design/concept development; 3) Design development and style selection; 4) Marketing the line; 5) Pre-production; and 6) Line optimization (May-Plumlee & Little, 1998) (see Figure 4).

![Diagram](image)

**Figure 4**: No-interval coherently phased product development model for apparel
Source: own illustration, based on May-Plumlee and Little (1998)

2.1.2.3 Apparel Product Development Process Model

According to Moretti and Junior (2017), the model from May-Plumlee and Little (1998) is not sufficiently focusing on the process phases and their relationships and can therefore be described as too superficial. For this reason, the ‘apparel product development process model’ (APDP), developed by Moretti and Junior (2017), is introduced in the following which is based on data gathered from eight companies, four professionals, and seven generic and specific apparel product development models. One of the models the APDP is based on is the one developed by May-Plumlee and Little (1998). The model concentrates on three different macro perspectives: ‘pre-development’, ‘development’, and ‘post-development’. The APDP is a reference model for the PD process for the fashion industry by providing guidance for organizations and improving the product development process of fashion products. Therefore, the model systematizes the process at a detailed level, focuses on fashion products, and considers the characteristics of the fashion industry. The APDP includes several areas of a
company: Top Management, Product Development, Management of Product Development, Commercial, Marketing, Purchasing, Production, Quality, and Engineering. Thus, the model highlights the need to use cross-functional teams in the product development of a fashion company to achieve good performance. Figure 5 illustrates the APDP by presenting the macros and their according phases (Moretti & Junior, 2017).

![Figure 5: Apparel product development process](source: own illustration, based on Moretti and Junior (2017))

The following paragraphs describe the model in greater detail and a summary of each macro, the relating phases, their objectives, and activities is given in the Table 1, 2, and 3. In the activity column, several gates are defined evaluating and filtering ideas or products (Moretti & Junior, 2017).

1) **Collection Planning**
This first phase focuses on the collection and the product development process which has to be in line with the strategic planning of a company. Therefore, relevant departments for the process, control indicators, and process requirements are defined and new market opportunities and threats are identified through analyses. Thereafter, a collection schedule is prepared which serves as a guide for the collection work team. Additionally, the production, marketing, and sales strategies which support the decision making within the whole collection development are defined. The results of this stage are evaluated and presented in a collection plan containing information like the collection schedule, performance indicators, and the target group (Moretti & Junior, 2017).

2) **Planning of the Collection Portfolio**
This phase aims at defining the collection portfolio, guides the collection creation, and enables its sales plan. In this regard, the collection plan of phase one helps defining the portfolio size, the product types as well as the quantity of products resulting in an updated collection plan (Moretti & Junior, 2017).
Table 1: Macro phase 'pre-development'  
Source: own illustration, based on Moretti and Junior (2017)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Phase objective</th>
<th>Activity</th>
</tr>
</thead>
</table>
| 1) Collection planning         | Identify the parties involved in the collection planning and assess the needs and controls for the process | Team definition  
Define the activities and sequences  
Prepare the schedule  
Develop performance indicators  
Analyze the sales data of past collections  
Scenario and target audience analysis  
Define the work sector  
Set the production strategies, marketing and sales  
Analyze the economic feasibility of the collection  
**Gate 1** – Evaluate the strategies for the collection  
Prepare the project plan |
| 2) Planning the collection portfolio | Set the product portfolio that will be developed in the collection | Set the portfolio size  
Set the types of apparel to be developed  
Specify the quantity of apparel to be developed by model and size  
**Gate 2** – Assess the final portfolio  
Document the decisions taken |

3) **Research the Market Trends**

The objective of this phase is to identify consumer needs and market trends by researching tendencies in models, fabrics, trims, and colors. In this context, the specifications of the styles are estimated and evaluated and the collection theme is defined. The output created in this process is the trend plan which comprises style information and the collection theme (Moretti & Junior, 2017).

4) **Definition of the Concept**

This part of the process aims at developing alternatives for the products of the collection. Herein, designers create numerous sketches of the fashion products, even more than required by the collection plan to allow paring down. Once the sketches are developed, the fabrics and trims for the collection are defined and evaluated. Further, the raw materials are determined and linked to the different product sketches which are tested regarding their economic feasibility. As a result, the concept plan is created containing information about the product sketches, the raw materials, a supplier list, the style data sheet, and the costs for each product (Moretti & Junior, 2017).

5) **Detailing**

Phase five seeks to specify the products designed in phase four. The raw materials are assessed to ensure the product quality and to gather information for the prototype construction. Subsequently, the technical drawings and product details are created based on the sketches from phase four (Moretti & Junior, 2017). Additionally, this phase develops prototypes, conducts fittings, tests the “usability and ergonomics, develops the operational sequence of each piece and develops the sizing of the approved apparel.” (Moretti & Junior, 2017, p. 255) Thereafter, the technical file for each product is created and the product’s economic feasibility is monitored. Lastly, the prototype is evaluated and approved by considering the planned margin. The phase results in technical and packaging specifications as well as estimates the product price (Moretti & Junior, 2017).
6) Pre-Production
This phase adjusts and optimizes the manufacturing process according to the collection’s needs. Further, it comprises the purchasing of the raw materials and the production of samples for sales representatives in the showroom. Therefore, the product price is specified and the resource demand for the collection is calculated. In order to enhance new production and sales processes, training is conducted before the production is released (Moretti & Junior, 2017). The outcome of this phase is “the showcase for sales representation, definition of costs, prices and profits of the apparel, installed production resources, trained labor force, manufactured products or production in progress.” (Moretti & Junior, 2017, p. 256)

7) Launching of the Collection
The collection launch aims at introducing the product into the market and covers the planning of sales and distribution processes as well as the marketing campaign. Therefore, the collection campaign is developed and the collection launch is managed and promoted. This phase results in a launch plan, sales process, and indications for the collection launch for the stores (Moretti & Junior, 2017).

Table 2: Macro phase 'development'
Source: own illustration, based on Moretti and Junior (2017)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Phase objective</th>
<th>Activity</th>
</tr>
</thead>
</table>
| 3) Research the market trends | Research the needs of consumers and the fashion market trends | Research the model trends  
Research the trends for fabrics and trims  
Research the color trends  
Generate ideas for the collection  
Gate 3.1 – Select ideas  
Set the style specifications for the collection  
Set the collection theme  
Gate 3.2 – Theme assessment  
Document the decisions taken |
| 4) Definition of the concept | Develop alternatives for collection | Create sketches of models (style design)  
Select the raw material for the collection  
Gate 4.1 – Filter the raw materials  
Associate the trends of materials/ colors with the models  
Monitor the economic feasibility of each product  
Gate 4.2 – Filter models  
Document the decisions taken |
| 5) Detailing | Detail product specifications and develop pilot parts | Submit the raw materials to quality testing  
Detail the architecture of the apparel (technical drawing)  
Develop the modeling apparel  
Produce pilot apparel of each piece in the collection  
Submit the apparel to trim, usability, and ergonomic testing  
Develop the operational sequence of each piece  
Develop the technical record of approved parts  
Develop the packaging for the collection  
Monitor the economic feasibility of each product  
Gate 5 – Assessment of the pilot apparel  
Modeling the measurement of the approved apparel |
Monitoring of the Product/ Process

The last phase controls and documents post-launch information and manages practices for proper product disposal. In doing so, a collection performance report, an evaluation of the customer satisfaction, and a guideline for product replacement are provided (Moretti & Junior, 2017).

Table 3: Macro phase ‘post-development’
Source: own illustration, based on Moretti and Junior (2017)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Phase objective</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>8) Monitor product/process</td>
<td>Monitor, document, and treat post-release information</td>
<td>Evaluation of customer satisfaction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monitor product performance (technical, economic, production, and services)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Encouragement of and assistance with disposal practices of the products (post-use)</td>
</tr>
</tbody>
</table>

2.1.3 Opportunities and Challenges in the Fashion Industry

Yeung and Leung (1995) point out that the product development process of a fashion company is critical and challenging at the same time. Independent of the sub-processes that are defined by a fashion company in the PD, there are several challenges and conclusive opportunities that need consideration.

According to Redfern and Davey (2003), fashion companies are facing two challenges in the product development. Firstly, there is the need to develop a product that is both unique and superior with regard to the competition and secondly, the features of the new product are required to be in line with the market orientation (Redfern & Davey, 2003). However, the literature research shows that there are more challenges in the fashion product development than the two mentioned by Redfern and Davey (2003).

Keiser and Garner (2012) state that the task of a product developer comprises to “deliver innovative products in the shortest possible time frame at the right price.” (p. 3) Due to globalization and low-cost pressures, companies are increasingly disseminating product development operations on a global level to exploit international capabilities and assets as well as to increase returns (Eppinger & Chitkara, 2006; Perks & Wong, 2003). Therefore,
activities in the product development are often outsourced (Contractor, Kumar, Kundu, & Pedersen, 2010), leading to a globally distributed and intertwined network as many actors are included in the product development process (Eppinger & Chitkara, 2006). This means that the developers need to coordinate all related processes across a globally fragmented supply chain. In addition, the participants of that supply chain often vary depending on the product (Keiser & Garner, 2012). De Luca and Atuahene-Gima (2007) state that a successful PD process needs a variety of knowledge input which combines several perspectives and generates new insights (De Luca & Atuahene-Gima, 2007). In addition, Keiser and Garner (2012) point out that the quality of communication is crucial when it comes to a product developer’s success.

Another occurring challenge claimed by Christopher (2000) refers to the growing number of possibilities assigned to globalization as well as an increasing demand for more specific products and raw materials. Moreover, the author adds that speed and flexibility are of higher value than costs and price (Christopher, 2000).

Despite the above mentioned challenges, the PD in the fashion industry offers diverse opportunities. Since the demand and the requirements of the customer are decisive for the product’s success, those preferences need to be acknowledged in the PD. Thus, implementing data mining methods is of high relevance (Lee, Tse, Ho, & Choy, 2015). However, being able to analyze customer data and to get the most value out of it is difficult (Shaw, Subramaniam, Tan, & Welge, 2001), but providing the customer with the demanded products at the right time offers the opportunity to increase the profitability of the company (Ip, Lee, Lau, & Ho, 2005). Hence, effective PD can positively impact sustained business growth (Chan & Ip, 2011).

With the rise of fast fashion, promoted by rapid changing consumer preferences and strong competition, fashion companies are faced with short product life cycles and reduced net margins. In order to satisfy the customer and make profit, the adoption of new technologies for core processes is required. This can enable the reduction of product lead times in the product development and production as well as time to market (Christopher, 2000). Eckert, Wynn, Clarkson, and Black (2008) suggest to use mass customization in the PD in order to meet the customers’ requirements. The customer has the opportunity to select the basic product design and can influence the style and materials, at least to a certain degree (Eckert et al., 2008). Little and Senanayake (2010) support this idea by stating that mass customization leads to product differentiation which fulfills different customer needs. When implementing co-creation or customization in the PD, customers are more likely to use their products longer. Thus, it may also have a positive impact on sustainability related issues (Kaneko, Kishita, & Umeda, 2018). However, the collaboration and constant data exchange between value stream partners is needed (Hren & Jezernik, 2009). In this context, De Silva, Rupasinghe, and Apeagyei (2019) point out that the creation of various ideas is enhanced through a collaborative atmosphere, which stresses the need to implement proper mechanisms in order to generate the optimal result. Keiser and Garner (2012) state that collaborative manufacturing may also offer the benefit of being able to create a vertical supply chain atmosphere without owning any of the supply chain partners. The authors further highlight:

Collaborative supply chains enhance a product developer’s ability to compete in terms of product innovation, cost, speed to market, manufacturing expertise, sustainability, and access to technology and resources to be more flexible in its response to changing market needs. (Keiser & Garner, 2012, p. 7)
Collaborative product development is thus providing opportunities for the PD in fashion. In general, it is aiming to reduce the cycle times of the PD process (Hren & Jezernik, 2009). The inputs a company gets from the customer can generate creative ideas (Nishikawa, Schreier, & Ogawa, 2013), lead to an improvement in the product variety (Al-Zu’bi & Tsinopoulos, 2012), and enhance the performance of the product (Lau, Tang, & Yam, 2010). However, collaborative PD is challenging due to the huge amount of data as well as product iterations. In order to cope with these challenges, technologies offer suitable opportunities (De Silva et al., 2019; Jimeno & Puerta, 2007). In addition to collaborative manufacturing and the PD, vertical integration bears opportunities by implying fewer links in the supply chain which leads to faster cycle times and the elimination of profit centers. Hence, it helps the product developers to get the right product at the right price and the right time to the customer (Keiser & Garner, 2012).

Applying computer applications in the product development process is required in today’s business. Implementing those technologies is of major importance to survive in the marketplace. Even though this is an opportunity to stay in business, it is a critical and challenging step (Burns et al., 2016). Nevertheless, those new technologies bear some opportunities since they positively impact the customer relationship (Nambisan, 2002; Vecchi & Buckley, 2016). One possible technology which can be implemented in the product development in the fashion industry is Virtual Reality (Jiang, 2017). In the following, this technology is introduced and its possible applications, opportunities and challenges for the PD are described.

### 2.2 Virtual Reality

#### 2.2.1 Definition of Virtual Reality

VR is a widespread technology providing users with an experience of interaction and immersion, and creating virtual environments which conquer the spatial and physical boundaries of the reality (ETRI, 2001, cited in Schina et al., 2016). More precisely, VR allows an individual to make artificial experiences in a virtual world which are created by computers and which are perceived as real by the user since this world allows him or her to see, hear, or grasp things just like in the reality (Mine, 1995; Ottosson, 2002). The user is able to interact with or navigate the virtually created environment through real time controlled or uncontrolled reactions (De Silva et al., 2019; Ottosson, 2002). In order to feel actively involved in the computer-generated world, the information noticed by the user’s senses need to be manipulated by the perceived environment, also referred to as Virtual Environment (VE) (Jimeno & Puerta, 2007).

Presence and interaction are the main two features of VR, which differentiate it from other technologies with a visual interface (Jimeno & Puerta, 2007). Presence means that the user reports a feeling of being transported into the virtual world and being a real part of it (Jimeno & Puerta, 2007; Schuemie, van Der Straaten, Krijn, & van Der Mast, 2001). As soon as a user-convenient VE is created, interaction between the user and the environment is enabled. Thus, interaction means that the user being situated in the VE is able to interact with and take actions in the synthetic world by means of hardware tools (Jimeno & Puerta, 2007).
2.2.2 Virtual Reality in the Product Development

The complex process of developing a product involves both the work on “its conceptual model and on its functional components.” (Schina et al., 2016, p. 198) In order to support the different product design phases and to manipulate and analyze the data concerning the functional and physical features of the product, specific technologies can be applied (Schina et al., 2016).

At present, VR systems provide diverse industries and fields with the opportunity to work in and interact within a VE (Schina et al., 2016). VR technologies can be traced back to the 1960s, and their importance in manufacturing and the product development process rose for reasons like their ability to enhance the effectiveness of the entire product development process, to become more cost competitive, to shorten time to market, to improve systematic procedures, and to initiate and examine interactions between users, operations, and objects (Dorozhkin, Vance, Rehn, & Lemessi, 2012; Ong & Nee, 2004; Shiratuddin & Zulkifli, 2001).

According to Ottosson (2002), VR is amongst the most growing technologies with a high potential in improving product design. This means it enables the digitalization, analysis, and simulation of all elements of a product, including its geometric shapes or physical properties as well as all processes associated with the lifecycle of the product. Further, VR in the product development is used for simulations, behavior studies, training of personal competences, and as a communication tool. With virtual communication, engineers can explore optimization potential of products, processes, and layouts as well as concepts can be accurately and circumstantially communicated to users and customers which is especially important in the product development (Schina et al., 2016).

VR is particularly useful for complicated systems in which many signals and diverse information have to be considered in terms of that many people are able to give their input and try different alternatives. Without VR, economic reasons and time constraints would impede this interchange (Schina et al., 2016). Therefore, Caputo and Di Gironimo (2007), cited in Schina et al. (2016), conclude that VR provides a solution to many challenges in the product design and the manufacturing industry. In addition, the higher the difficulties, complexities, and costs of set-ups are, the more beneficial is the use of VR to explore and establish appropriate solutions in engineering design (Schina et al., 2016).

However, the implementation of VR comes along with high economic threshold (Schina et al., 2016) just as side effects can occur by using VR systems in the short and long term. The short term effects include symptoms such as “feeling sick, visual fatigue and spatial disorientation” (Jimeno & Puerta, 2007, p. 872), but which depend on the kind of interface used, the attached delay of the projection as well as the immersion level of the user into the virtual environment. These side effects can be reduced or overcome with an increased and repetitive use of the devices. Nonetheless, there are different opinions about the probability of irreversible damage in the long term (Jimeno & Puerta, 2007). Further, the application of VR in the product development in the fashion industry is limited and in its early stages, even though it offers new opportunities in this area (De Silva et al., 2019; Ottosson, 2002).
**2.2.3 Areas of Application**

Despite the above mentioned drawbacks and risks, VR implies a noticeable potential to reduce time and costs in the product development, while improving quality and applicability of the products (Ottosson, 2002). It can be used in diverse areas of the product development, including Virtual Training (VT), Virtual Prototyping (VP), Virtual Manufacturing (VM), and Virtual Factory (VF) (Schina et al., 2016). In the following, these applications are explained in greater detail. Due to the lacking literature of this topic related to the fashion industry, they refer to manufacturing industries in general. However, since some literature about Virtual Prototyping in the fashion industry could be identified, the corresponding paragraph includes a few examples from this industry.

**Virtual Training**

Staff from almost all industrial sectors require trainings on a continuous basis. Especially the rapid development of new technologies and related complexities call for increased trainings to ensure the maintenance of a skilled and competent workforce (Brough et al., 2007). Brough et al. (2007) state that existing trainings can be enhanced with respect to cost and time expenditures and effectiveness through the application of computer-based technologies such as VR. The use of VR for training purposes has been widely applied and is regarded as a technique to train employees’ skills in terms of manufacturing and related processes. By the use of forefront VR technology, training is held in a simulated environment which seems realistic to the actual training facility (Shiratuddin & Zulkifli, 2001).

VT can be a considerable option when diverse employees from fragmented areas need to participate, or when employees need to be trained on a consistent basis, no matter when or where they are. VR in trainings allows all employees to exercise current or new functions in an artificial but secure environment and to realize how a product materializes as it processes through the manufacturing system (Shiratuddin & Zulkifli, 2001). Users can directly interact with the simulated objects and learn from the impacts resulting from the interactions (Jia, Bhatti, & Nahavandi, 2009). Thereby, they do not only become acquainted with their own tasks but they can better understand the whole manufacturing process and how their individual responsibilities fit into it. This may lead to significant improvements in manufacturing efficiency (Shiratuddin & Zulkifli, 2001). Furthermore, remarkable cost savings can be achieved with VT, since the times needed for the implementation of diverse training scenarios are shorter and engineering models that already exist can be reused. Also, through the use of VR-based training, the time interval between the design of the product and the actual manufacturing can be reduced due to the independence of hardware devices for trainings (Jia et al., 2009).

Pantelidis (1996), cited in Pantelidis (2009), provides a summary showing when VR for trainings and educational purposes is beneficial and when it is not. The most important arguments are highlighted in the following.

The author states that VR should be used when training in a real environment is not feasible, not convenient, not secure, or not easy enough to be performed. Additionally, the use of VR in trainings is advantageous, since it can be more encouraging and exciting for the participants than a real training. Furthermore, the author mentions the benefit of having less travel or logistics expenditures with VT when people from different places need to take part in the training. Moreover, training simulations are useful when it is important for a group to share joint experiences in a joint environment and when the creation of a simulated environment is
crucial to the training’s aim. Apart from this, the use of VR in trainings is of advantage when information need to be visualized, manipulated, or rearranged by the use of graphical symbols for a better comprehension. And lastly, it presents a real opportunity when errors made by the training participants on the real object would discourage them, harm the environment, accidentally cause damage to property or equipment, or be too costly (Pantelidis, 1996, cited in Pantelidis, 2009).

On the other hand, Pantelidis (1996), cited in Pantelidis (2009), says that VR in trainings should not be applied when a training with real objects or direct interaction between people is necessary. Further, the author mentions the risk of emotional or physical damage when conducting VTs. An additional threat concerns the fact that in some cases, the virtual simulation may be so credible that the user gets confused with differentiating the virtual from the real environment. And finally, it should be mentioned that VR represents a high cost factor which is often disproportionate to the expected training outcome (Pantelidis, 1996, cited in Pantelidis, 2009).

Virtual Prototyping
Prototyping presents an important step in the product development process as it allows the product development team to optimize the product design and to remove weak points (Jimeno & Puerta, 2007; Seth, Vance, & Oliver, 2011). According to Bordegoni (2011), the purpose of prototyping in a product design process is to find alternative design options, to validate performance, and to test theories before the new product goes into production. Prototyping is a common method to assess the product design during the development phase and to make corrections in case of problems or misunderstandings in the conceptual design stage. Depending on their purposes and functions during a test, there are different types of prototypes. For instance, some prototypes incorporate all the characteristics of a product whereas others only possess a few properties. In addition, there are different kinds of prototype implementations (Bordegoni, 2011).

‘Physical’ prototypes intend the design of a partly or fully functional product, which is generally a quite expensive activity and therefore carried out at the end stage of the design, at a time when most design issues have already been detected and, at best, resolved (Bordegoni, 2011).

‘Rapid’ prototypes present a less expensive but also less extensive way to assess the effectiveness of the product design features (Bordegoni, 2011).

‘Virtual’ prototypes may be a solution to overcome the expensive physical and less comprehensive rapid prototyping approaches. Virtual Prototyping seeks to be supportive in the validation of the initial concept of the product design, but postpones the complete validation of the intended final product to the end of the design process with a fully functional prototype. In doing so, a design review can be assessed before creating physical products and hence, the amount of physical prototypes created during the product development process can be significantly decreased (Bordegoni, 2011).

VP refers to the application of VR in computer-aided design (CAD) and computer-aided manufacturing (CAM) processes (Jimeno & Puerta, 2007) and anticipates an intended product, which is not existing in the real environment yet (Bordegoni, 2011). Virtual prototypes are used by designers, engineers, and end users to test and assess an intended product’s aesthetic features, its functionality, ergonomics, and usefulness. Virtual prototypes
are an increasingly popular practice, since they “are easy-to-modify, share, represent in different ways and enriched with additional information.” (Bordegoni, 2011, p. 119) Gobbetti, Scateni, and Agus (2000) explain that VP aims at moving away from the expensive practice of creating physical mock-ups, but instead developing digital ones which are able to imitate the behavior and the optical appearance of an object on the basis of a computer. More precisely, the application of a VR software allows to realistically simulate and visualize all important product features and its 3D movement behavior in a synthetic environment in order to adjust and enhance its design before developing the physical prototype (Schina et al., 2016; Shiratuddin & Zulkifli, 2001). Hence, by the use of VP, changes in design can be undertaken easily during the conceptual design phase while reducing costs and optimizing the product (Bordegoni, 2011; Seth et al., 2011).

The virtual product must possess the important characteristics of the final product. This also concerns the haptic features (Jimeno & Puerta, 2007), though they are difficult to emulate in an immersive environment (De Silva et al., 2019). However, technological advances of Virtual Reality allow to evaluate product characteristics that are not only associated with the product’s aesthetic aspects but also with the utilization of the product. For instance, the development of haptic technologies enables physical interaction with the simulated products and progresses in sonification technologies allow the virtual products to emit realistic sounds. For this reason, VP facilitates to assess more and more product aspects with a high degree of fidelity, meaning the level of resemblance with the intended product (Bordegoni, 2011). In addition to this, VP can also be used in manufacturing industries to detect potential loopholes “in a faster, less expensive, and safer way than with traditional physical prototypes, thus shortening design cycle times and reducing overall costs.” (Schina et al., 2016, pp. 200–201) Hence, virtual prototypes are advantageous compared to physical prototypes as they are less expensive, allow closer collaboration between value chain partners, and take less time to be created (Jimeno & Puerta, 2007) and therefore enhance the efficiency in the product development process (McLeod, 2001).

If the virtual prototype is effectively created, it can provide several benefits compared to a physical sample. Firstly, a significant decrease of time needed for the product development and of manufacturing costs can be expected due to the reduced amount of physical prototypes. Secondly, the possibility of continuous maintenance of digital mock-ups in synchronization with the design allows to utilize them for documentary purposes and as a base to facilitate the communication between engineers from different areas. Thirdly, VP provides the ability to use the virtual prototypes during collaborative design meetings even though geographically fragmented actors need to participate (Gobbetti et al., 2000). Next, the problems arising during manufacturing, design, or planning processes can be identified promptly, resulting in a reduced need of physical reproductions and consequently, in substantial cost reductions (Jimeno & Puerta, 2007). In addition to reduced costs, VP can lead to a decreasing use of materials and less material waste (McHugh & Zhang, 2011). As soon as the virtual prototype is created, it can be converted into a physical product, or it can be passed to customers for their remarks (Jimeno & Puerta, 2007).

In order to gain a competitive edge, a company’s strategic aim should not only be to fulfill customers’ requirements but to completely satisfy them by analyzing what customers really need and integrating the Voice of the Customer into the product development process (Bordegoni, 2011). By using VP, it can be assured that the designed product meets the customer demand, since it allows end users to pre-evaluate the product (Bordegoni, 2011). With regard to VP of garments, another important advantage to be mentioned is that garments
can be designed and monitored according to a customer’s exact body shape without being physically present (Jevšnik, Stjepanovič, & Rudolf, 2017).

Despite all the above mentioned benefits, diverse problems can occur with regard to VP approaches. Bjoerkli (2015) mentions the insufficient fidelity of the tactile feedback to the user in the simulated environment by means of haptic tools as one drawback of VP. The reasons for this are linked to the lack of understanding of how the human perceptual system works in detail and to problems arising during the end or decoding of touch signals (Magnenat-Thalmann, 2010). Another reason is the restricted disposability of “efficient-and-affordable multipurpose devices enabling direct haptic interaction with virtual objects.” (Magnenat-Thalmann, 2010, p. 124) A further VP related problem present the uncomfortable devices that need to be worn by the users to immerse in the virtual world (Bjoerkli, 2015).

Regarding clothes, one natural characteristic is that they are highly malleable. Hence, a potential disadvantage that can arise by the use of VP in fashion is that it might not be able to accurately imitate the non-linear and deformed parts of the garment, like wrinkles or folds (Volino, Cordier, & Magnenat-Thalmann, 2005). Another issue related to VP in clothing is that the way a garment falls highly depends on its interaction with a person’s body and with other garments that person wears. This calls for elaborated systems to find out the geometrical contact points which restrain the behavior of the garment, and to incorporate them in the mechanical mock-up. However, for applications in real-time, the computer simulation of a garment is often based on approximated or simplified techniques and hence, it needs to abandon some precision of the mechanical behavior (Volino et al., 2005). Virtual fitting can be regarded as a further challenge because the garment's fit on a body is highly dependent on “physical and mechanical properties such as tendency of the fabric to stretch, shrink, distort, and drape due to stresses induced during use under static and dynamic situations.” (Papahristou & Bilalis, 2017) For this reason, the authors argue that in some cases, a physical prototype is needed (Papahristou & Bilalis, 2017).

Papahristou and Bilalis (2017) mention the users’ lack of technical knowledge as a main disadvantage of 3D virtual prototyping since it takes a lot of time to learn how to use this new technology. However, if not enough effort is invested in learning the handling of this technology, it becomes inefficient (Papahristou & Bilalis, 2017).

**Virtual Manufacturing**

VM refers to achieving a synthetic, integrated environment compiled of different software tools and systems in order to provide bespoke solutions for the whole product development process. In this context, it aims at enabling new ways of developing, assessing, and simulating complex systems digitally as well as delivering an approach that evaluates outcomes of new production decisions before realizing the physical product (Porto, Sacco, & Souza, 2006). According to Banerjee and Zetu (2001), cited in Porto et al. (2006), VM is used to prognosticate, and to this effect also avoid, potential inefficiencies and problems in the functionality and producibility of products. This implicates cost and time reductions due to the early problem identification and the evaluation of various design alternatives (Porto et al., 2006). Moreover, it is claimed that “with the effective use of computers, audiovisual and sensory displays” (Porto et al., 2006, p. 726) the integration of designer and customer requirements is improved by enabling interaction between the user and the virtual world. This further allows engineers to create and modify products and processes in real time by reviewing immediate effects of alterations (Porto et al., 2006).
In this regard, VM comprises the simulation of products and the related manufacturing processes by using simulation technology. With this, firms are able to enhance key factors which have a direct impact on the profitability of the fabricated products (Jimeno & Puerta, 2007). These key factors comprise “manufacturability, final shape, residual stress levels, and product durability” (Jimeno & Puerta, 2007, p. 871) They influence the profitability directly, since they are able to decrease production costs and the utilization of materials. In addition, VM is able to reduce tooling costs, decrease the number of physical prototypes needed, and minimize waste of material (Jimeno & Puerta, 2007). Porto et al. (2006) also conclude that a VM environment improves concurrence of activities as well as enhances the integration of product and process design phases.

Furthermore, VM enables companies to enhance processes by bringing new products faster to the market in a more cost-effective way (Porto et al., 2006). Hence, VR allows to virtually investigate objects through different 2D and 3D representations which reduce the abstraction level as well as increase the interaction with the users in a multi-dimensional context conveying the perception of being part of the same environment (Shiratuddin & Zulkifli, 2001). Moreover, VR facilitates to depict principles, objects, processes, and activities (Marinov, 2001, cited in Schina et al., 2016) providing graphical interfaces that make a quick understanding possible through visualization and experience (Choi, Jung, & Noh, 2015). Consequently, VR serves as a visualization tool in VM (Shiratuddin & Zulkifli, 2001).

In addition, by integrating manufacturing data into the virtual design process, movements and operations can be virtually examined and different product behaviors can be simulated and analyzed according to modifications. This has positive effects in terms of simplifying the optimization work required in the manufacturing process to investigate practicability, applicability, and accuracy of the processes, decreasing the likelihood of errors in manufacturing processes, and guaranteeing that decisions of the design phase are reflected in manufacturing concerns (Schina et al., 2016).

Porto et al. (2006) continue that VM can support the product development process in various phases which are further explained in the following.

In the ‘concept design phase’, a basic description of functions and characteristics of the product is given that serve as an information base for subsequent phases. Here, VM supports the creation and selection of product concept alternatives. Designers can analyze and manipulate the surface of virtual models instead of building numerous physical models to get the same level of accuracy. This allows an early detection of mistakes and inconsistencies in the product shape. For the ‘product design phase’, the authors emphasize that VM tools positively influence refinements in styling, shape, and design, just as the assessment and analysis of components, systems, and the whole product. Thus, the user can virtually simulate and anticipate the product’s functional behavior in the same way as it would be in the real world. The ‘process design phase’ refers to the implementation of VM in the establishment and verification of production and assembly processes. This allows to create 3D prototypes which can be assembled and transferred into a simulation tool that demonstrates the assembly sequence in order to disclose potential problems and clashes between components and parts. Regarding the ‘production pilot phase’, the authors state that VM enhances assembly and production line capacities by assuring an ameliorated flow of material. By simulating a production system, modification impacts of production constraints are visualized providing results of the production rate, throughput time analysis, machine and resource utilization as well as bottleneck identification (Porto et al., 2006).
Porto et al. (2006) mention that problems in the data import and export between different systems are one of the biggest obstacles in VM due to a lack of data and an incompatibility of systems. However, once this problem is solved, VM enables companies to amend critical factors and inefficiencies in the production. In addition, Shiratuddin and Zulkifli (2001) claim that VM provides an efficient and precise evaluation and control of the systems and factory as a whole.

**Virtual Factory**

There are several complex factors that have to be considered in designing a production facility. Firstly, physical space must be created for equipment and its associated operators. Secondly, there is space required for “maintenance, loading/unloading, utilities, debris removal, tool storage, and inspection” (Shiratuddin & Zulkifli, 2001, p. 8). Furthermore, it is necessary to consider the flow of products, lighting, capacities of machines, sequence of performed operations as well as the variety of applications in order to find the ideal position for the equipment. This process gains complexity with an increasing number of machines. Therefore, visualization on a computer simulation can facilitate trade-offs (Shiratuddin & Zulkifli, 2001).

VF explains how VR can be applied to the production facility design (Shiratuddin & Zulkifli, 2001). It permits to model processes, correlations, and dependencies as well as material and data flows in the whole factory (Sacco, Pedrazzoli, & Terkaj, 2010). Further, it serves as a virtual representation of the actual factory including its construction, machinery, and supporting equipment (Jain, Choong, Aye, & Luo, 2001; Shariatzadeh, Sivard, & Chen, 2012), and simulates production in a Virtual Factory environment enabling optimization prior to actual production (Yang, Ahn, & Seo, 2006). Hence, VF aims at supporting the evaluation and improvement of production while maintaining a production of high quantities and many variations (Eriksson, Sedelius, Berglund, & Johansson, 2018).

Shiratuddin and Zulkifli (2001) emphasize that VF allows users to analyze and identify faults in manufacturing processes before they appear on the factory floor as well as teaching the environment to work optimally together. Moreover, they conclude that VF impacts several aspects, such as building a computer-based environment that precisely simulates single production processes and the whole production company, reducing production costs, enhancing time to market, and decreasing development time. Subsequently, early and precise estimates of manufacturability and affordability are possible just as a seamless transfer of information is developed (Shiratuddin & Zulkifli, 2001). Thus, in its initial stage, VF can be viewed as a first approach to provide a virtually suitable environment for inter- and intra-organizational collaborations together with enabling virtual co-working environments (Schina et al., 2016). Further, Rohrer (2000) emphasizes that VF enables the sharing of ideas between various functions and people. This serves as a transfer of knowledge and communication of people who are physically not at the same place (Eriksson et al., 2018). VF can also be applied to achieve time and cost savings (Shariatzadeh et al., 2012) by assessing design modifications and process improvements, and simulating factory operations. Therefore, planning time is increased which, in turn, reduces realization time just as it allows to execute product and process developments concurrently instead of sequentially (Schuh et al., 2011).

Nevertheless, in order to build and realize a Virtual Factory, virtual data management, automatization, flexible and consistent simulation as well as communication and integration are crucial (Choi, Kim, & Noh, 2015). This imposes a challenge to most software tools as they are not equipped with these capabilities. In addition, it is necessary to evade design
mistakes and miscalculations in measurements and modeling as they would implicate tremendous costs (Lindskog, Vallhagen, & Johansson, 2017).

2.2.4 Opportunities and Challenges of Virtual Reality in the Product Development

The previous sub-chapters present a number of opportunities and challenges regarding the application of VR in the PD process in the four areas of Virtual Training, Virtual Prototyping, Virtual Manufacturing, and Virtual Factory in manufacturing industries. These are summarized in Table 4 and 5. By placing a checkmark in the according boxes, the specified opportunities and challenges were assigned to the areas they apply to and according sources were indicated.

Beyond that, several opportunities and challenges were identified that apply to the application of VR in the product development in general and play an equal role in the analysis part of this thesis. According to that, time and cost reductions just as process improvements are mentioned as key opportunities, whereas high costs for the acquirement and implementation of VR (Schina et al., 2016) as well as the risk of sickness (Jimeno & Puerta, 2007) are identified as general challenges.
Table 4: Opportunities of VR in the PD  
Source: own illustration

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>VT</th>
<th>VP</th>
<th>VM</th>
<th>VF</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized product design features</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VP: Schina et al. (2016), VM: Schina et al. (2016)</td>
</tr>
<tr>
<td>Concurrence of activities</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VM: Porto et al. (2006), VF: Schuh et al. (2011)</td>
</tr>
<tr>
<td>Bespoke solutions for the PD process</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VM: Porto et al. (2006)</td>
</tr>
<tr>
<td>Evaluation of product and production decisions prior to the product realization</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VP: Schina et al. (2016) VM: Porto et al. (2006)</td>
</tr>
<tr>
<td>Enhanced assembly and production line capacities</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VM: Porto et al. (2006)</td>
</tr>
<tr>
<td>Enhanced evaluation and control of systems</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VM: Shiratuddin &amp; Zulkifli (2001)</td>
</tr>
<tr>
<td>Optimized floor layout</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VF: Shiratuddin &amp; Zulkifli (2001)</td>
</tr>
<tr>
<td>Seamless transfer of information</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VF: Shiratuddin &amp; Zulkifli (2001)</td>
</tr>
<tr>
<td>Constant training for skilled employees</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VT: Brough et al. (2007)</td>
</tr>
<tr>
<td>Increased flexibility</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VT: Shiratuddin &amp; Zulkifli (2001)</td>
</tr>
<tr>
<td>Improved documentation of the PD process</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VP: Gobbetti et al. (2000)</td>
</tr>
<tr>
<td>Integration of VOC in the PD</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VP: Bordegoni (2011)</td>
</tr>
<tr>
<td>Tailored design to exact body shapes</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>VP: Jevšnik et al. (2017)</td>
</tr>
</tbody>
</table>
**Table 5: Challenges of VR in the PD**  
Source: own illustration

<table>
<thead>
<tr>
<th>Challenges</th>
<th>VT</th>
<th>VP</th>
<th>VM</th>
<th>VF</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient software capabilities</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td>VF: Choi, Kim, and Noh (2014)</td>
</tr>
<tr>
<td>Lack of data</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VM: Porto et al. (2006)</td>
</tr>
<tr>
<td>Incompatibility of systems</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VM: Porto et al. (2006)</td>
</tr>
<tr>
<td>Mistakes in measurements</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td>VF: Lindskog et al. (2017)</td>
</tr>
<tr>
<td>Risk of emotional or physical damage</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VT: Pantelidis (1996), cited in Pantelidis (2009)</td>
</tr>
<tr>
<td>Insufficient fidelity of tactile feedback</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VP: Bjoerkli (2015)</td>
</tr>
<tr>
<td>Uncomfortable devices</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VP: Bjoerkli (2015)</td>
</tr>
<tr>
<td>Risk of inaccurate imitation of the product</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VP: Volino et al. (2005)</td>
</tr>
<tr>
<td>Lack of technical knowledge of users</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VP: Papahristou &amp; Bilalis (2017)</td>
</tr>
<tr>
<td>High time effort to learn the handling of VR tools</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>VP: Papahristou &amp; Bilalis (2017)</td>
</tr>
</tbody>
</table>
3 Methodology

The third chapter describes the methodology applied in this thesis. Therefore, an overview of the methodological procedure is given followed by a summary of the state of the art. The next sub-chapters cover the sampling method as well as the data collection. Last but not least, the evaluation of the gathered data is described.

3.1 Methodological Procedure

The topic of the application of VR in the PD in the fashion industry has not been thoroughly covered in the literature yet. When there is only little or no prior research available, Bryman (2012) suggests to take an exploratory stance in order to gain initial but deep insights into a topic. To get to the heart of this subject of research and to develop a profound understanding regarding the opportunities and challenges of VR in the PD process of fashion companies, this study is based on a qualitative research approach and data is collected by means of semi-structured interviews.

The ontological position of this research study is largely grounded in ‘constructionism’ which assumes that social phenomena and related meanings are constantly constructed by social actors (Bryman, 2012). More specifically, the research only mirrors “a specific version of social reality, rather than one that can be regarded as definitive.” (Bryman, 2012, p. 33) With regard to this research study, this means that the results from the semi-structured interviews solely reflect how the respondents perceive the topic of VR in the PD process in the fashion industry. The results of this study should thus not be denoted as a definitive reality external to social actors but as a ‘reality’ which was constructed by the actors themselves. In line with the constructionist view on the world, the authors of this study assigned this research to the epistemological position of ‘interpretivism’, which suggests that studies in social sciences need a distinct approach to the research procedure in natural sciences (Bryman, 2012). As concerns this research study, the data evaluation and analysis did not use any calculation methods from the natural sciences. Rather, a thematic analysis was conducted in order to depict relevant patterns to the research topic and to gain an understanding of the attitude of individual product developers from the fashion industry towards the topic of VR in the PD process in fashion.

According to Bryman (2012), the most common way of conducting qualitative research is to generate theory out of the collection and evaluation of data, hence following an inductive reasoning approach. However, this is not a fix and clear-cut rule that always applies to qualitative research. Rather, it can also play an important role in the testing of theories that are defined prior to the data collection (Bryman, 2012). This process, which starts with an existing theory or generalization and strives to test it according to its application to particular instances, is also known as deductive reasoning (Hyde, 2000). Hyde (2000) states that using a deductive reasoning approach in qualitative research “can represent an important step towards assuring conviction in qualitative research findings.” (p. 3)

With regard to this study, a lot of literature about VR in the PD of manufacturing industries in general could be found as well as relating opportunities and challenges. This existing body of literature was used to deduct the themes for the thematic analysis and develop the interview questions to find out whether and why product developers from the fashion industry regard the general findings from the literature as important for this particular industry, and whether the identified opportunities and challenges can be applied to it. Thus, this study is embedded
in a qualitative research design with the aim to develop a profound understanding of the investigated topic by using deductive reasoning to find out whether existing theory about VR in the product development of manufacturing industries can be projected onto the fashion industry.

Figure 6 provides an overview of the methodological procedure of this study. Each step is explained separately in the subsequent paragraphs.

![Figure 6: Overview of the methodological procedure](image.png)

**Objective**
- Elaborate the context of PD, PD in the fashion industry, and VR in the PD as a theoretical foundation for the empirical analysis
- Select a sample for the data collection
- Collect data to find out the areas of application of VR in the PD in the fashion industry as well as relating challenges and opportunities
- Evaluate the collected data to answer the research questions

**Method**
- Narrative literature review
- Snowball sampling
- Semi-structured interviews
- Thematic analysis

Figure 6: Overview of the methodological procedure
Source: own illustration

### 3.2 State of the Art

The literature review aimed at providing a detailed overview of the topics of the PD in general and in the fashion industry, VR, and the use of VR in the PD process. Thereupon, questions for the semi-structured interviews with five product developers working in global fashion companies could be formulated, which formed the basis to answer the research questions.

Much research could be found on the topics of PD in general and in the fashion industry in diverse books and peer-reviewed journal articles. The topic of VR and its areas of application are also thoroughly covered in the literature. However, when it comes to the application of VR in the product development process of fashion, a lack of research could be identified. Therefore, the procedure to find relevant literature to the research topic mainly followed a narrative review approach. According to Bryman (2012), a narrative review of the literature is an unsure process by nature in a way that the researcher does not know from the outset where the review will take him or her. Hence, the scope of the literature review is broader and less concrete than in a pure systematic literature review (Bryman, 2012). In doing so, the literature review departed from the originally intended search for the application of VR in the product development process in the fashion industry, but examined the topic of VR in the product development of manufacturing industries in general and what opportunities and challenges VR implies for such industries. As suggested by Bryman (2012), the authors of this study included some systematic search procedures into the narrative review in order to provide some structure to the search process. For instance, the authors oriented on the research questions of this study and used specific key terms to control and narrow the search process.
The literature review formed the foundation for the interview questions and the thematic analysis in order to find out whether or not the general research about VR in the product development of manufacturing industries can also be applied to the fashion industry.

3.3 Sampling

As Figure 6 shows, the sampling method applied for this research study was a snowball sampling approach. According to Bryman (2012), snowball sampling is a form of purposive sampling which indicates that the author’s research question is the starting point of the sampling considerations. Hence, the sample units for the research are selected strategically and not randomly based on key characteristics that are important to the research question. More precisely, snowball sampling starts with contacting a small group of respondents that are relevant to the investigated research topic. This small group, in turn, is the contact source to find further potential participants relevant to the study (Bryman, 2012). Snowball sampling is a widely used sampling method in qualitative research and particularly useful when insider knowledge is required (Biernacki & Waldorf, 1981).

The authors of this study are aware of the fact that snowball sampling is usually used for bigger samples and that it is a process that repeats several times (Noy, 2008). However, due to the limited scope and timeframe of this study, a bigger sample was not within the realm of possibility. Thus, the authors of this study agreed that despite of the small sample size of this study, the sampling method applied refers to the snowball sampling approach. They started with contacting a very small amount of product developers of several fashion companies based on their own network. Those product developers forwarded further contacts of fashion product developers that could be relevant to the investigated topic. In doing so, a sample of five product developers working for four different fashion companies was created.

3.4 Data Collection

In order to find an answer to the research questions, data was collected on the basis of five semi-structured interviews with product developers from the fashion industry. Due to legal and privacy issues, the company names as well as the names of the respondents stay anonymous. As a substitute for the respondents’ names, letters from A to E were used and the company names were replaced with numbers from 1 to 4 whenever they were mentioned in the text. However, it can be indicated that four out of the five interviewees work in different companies and that all fashion companies operate on a global basis. In addition, the age range of the interviewees spans from 21 to 28 years and their work experience from one to four and a half years. It should be noted that none of the chosen product developers had extensive work experience with VR. Nonetheless, they were considered as important to this research study, as this technology is to date hardly applied in any fashion company and therefore, this thesis aims to gain initial insights into that topic and provide a foundation on which further research can be built.

A semi-structured interview consists of a range of questions which are arranged in a general order on an interview sheet (interview guide), but can be asked in various sequences. Furthermore, the interviewer is usually free to ask additional questions in reaction to responses of the interviewees when they are seen as significant to the research topic (Bryman, 2012). Semi-structured interviews have some advantages when compared to unstructured interviews. These advantages are evident when the interview needs to establish some control over the topics to be covered throughout the interview. On the other hand, semi-structured
interviews are more beneficial than structured interviews when open questions are needed to get more comprehensive and detailed answers (Given, 2008).

For the semi-structured interviews of this study, an interview guide with a total of 20 questions was developed. This guide was divided into two parts. The first part included eight relevant general questions about the interviewee, such as the interviewee’s name, the company he or she is working in, the interviewee’s work experience in the product development, etc. The second part covered the research topic of VR in the PD of fashion companies and comprised twelve open questions about VR, the current status of VR in the respective companies, the interviewee’s attitude towards VR in the PD of fashion, what application areas, opportunities, and challenges the interviewee sees with respect to the implementation of VR in the PD in fashion, etc. (see Appendix II) With regard to VR and the areas of application, the interviewees were first asked to define these terms according to their own understanding. Subsequently, to ensure that everyone is on the same page, the authors of this study provided the interviewees with the definitions used in this research study. Furthermore, they put particular importance to the formulation of the questions, so that the interviewees would not have been influenced by the way the questions were asked. The interviews were conducted via Facetime between May 4, 2019 and May 8, 2019 and lasted between 22 to 52 minutes (see Appendix III).

3.5 Data Evaluation

In a next step, the collected data of the semi-structured interviews were evaluated using a thematic analysis. According to Braun and Clarke (2006), a thematic analysis is an elementary method in qualitative research since it provides a helpful and flexible tool to analyze qualitative data in a profound and comprehensive manner. More specifically, this method enables the identification, analysis, and reporting of themes arising within the data (Braun & Clarke, 2006). Boyatzis (1998) describes a theme as a pattern identified in the data which should be organized and described at a minimum, but interpreted at a maximum. Braun and Clarke (2006) point out that themes do not just emerge from the data. Rather, the themes and patterns need to be actively detected and selected by the researcher according to their relevance to the investigated research topic (Taylor & Ussher, 2001). Braun and Clarke (2006) further state that a thematic analysis is not stipulated to any existing theoretical framework, but can be applied in diverse theoretical frameworks. What matters is that the aim of the researcher’s study is conform with it and the method applied. In this context, it is vital to admit one’s own theoretical stance with regard to the qualitative research (Braun & Clarke, 2006). As already mentioned in chapter 3.1, the theoretical position taken in this research referred to ‘constructionism’ acknowledging the ways of how individual people attach and construct meanings to social phenomena (Bryman, 2012). Therefore, the thematic analysis did not aim to draw any generalizations from the data, but to reflect and understand how the interviewed product developers perceived and felt about VR in the product development of fashion and to interpret what this could mean for the fashion industry.

Braun and Clarke (2006) provide a checklist of criteria for a good thematic analysis, which has been applied on this study (see Table 6). This list includes the processes of transcription, coding, analysis, overall, and written report (Braun & Clarke, 2006). The first three processes are thoroughly described in the subsequent paragraphs. Since the remaining two processes arise from the overall methodology, they are not explicitly covered in a separate section.
Table 6: Checklist of criteria for a good thematic analysis
Source: own illustration, based on Braun and Clarke (2006)

<table>
<thead>
<tr>
<th>Process</th>
<th>No.</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transcription</td>
<td>1</td>
<td>The data have been transcribed to an appropriate level of detail, and the transcripts have been checked against the tapes for ‘accuracy’.</td>
</tr>
<tr>
<td>Coding</td>
<td>2</td>
<td>Each data item has been given equal attention in the coding process.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Themes have not been generated from a few vivid examples (an anecdotal approach), but instead the coding process has been thorough, inclusive and comprehensive.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>All relevant extracts for each theme have been collated.</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Themes have been checked against each other and back to the original data set.</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Themes are internally coherent, consistent, and distinctive.</td>
</tr>
<tr>
<td>Analysis</td>
<td>7</td>
<td>Data have been analyzed, interpreted, and made sense of rather than just paraphrased or described.</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Analysis and data match each other; the extracts illustrate the analytic claims.</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Analysis tells a convincing and well-organized story about the data and topic.</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>A good balance between analytic, narrative, and illustrative extracts is provided.</td>
</tr>
<tr>
<td>Overall</td>
<td>11</td>
<td>Enough time has been allocated to complete all phases of the analysis adequately, without rushing a phase.</td>
</tr>
<tr>
<td>Written report</td>
<td>12</td>
<td>The assumptions about, and specific approach to, thematic analysis are clearly explicated.</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>There is a good fit between what you claim you do, and what you show you have done – i.e., described method and reported analysis are consistent.</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>The language and concepts used in the report are consistent with the epistemological position of the analysis.</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>The researcher is positioned as active in the research process; themes do not just ‘emerge’.</td>
</tr>
</tbody>
</table>

The accurateness of transcribing the recorded interviews was assured by the use of the transcription program ‘Trint’. This program allows a fast and accurate voice-to-text transcription due to its use of automated speech recognition. Moreover, ‘Trint’ provides an editing program, ‘Trint Editor’, which sticks the transcribed text to the original audio or video source and which allows the search, verification, or correction of the transcription within this program (Trint, 2019). The recorded audio files of the semi-structured interviews were uploaded in the transcription program and converted into a text within a few minutes. While reading the transcribed text, the authors of this study were able to listen to the corresponding audio passage simultaneously and edit the text in case of incorrectly replicated words. As soon as the transcribed text was checked against the audio file, it was downloaded and saved as a Word document.

According to Boyatzis (1998), a thematic analysis is a procedure for encoding qualitative data. Therefore, explicit codes need to be defined which can imply “a list of themes; a complex model with themes, indicators, and qualifications that are causally related; or something in between these two forms.” (Boyatzis, 1998, p. 4) The author continues that the generation of themes can either take place in an inductive way from the raw data or in a
deductive way from precedent research and theories (Boyatzis, 1998). Concerning this research study, the latter option was chosen because the themes found in the literature would provide some structure to the encoding process of the interview data. Further, it would help to find out whether and how far the literature about VR in the PD process of manufacturing industries as well as relating and general opportunities and challenges would apply to the fashion industry. In line with the aim of finding an answer to the research questions, the themes were elaborated on the basis of the four areas of VR applications in manufacturing industries (see chapter 2.2.3), and the opportunities and challenges of VR in the PD process in general, and with respect to the four areas of application (see chapter 2.2.4). Hence, the areas of application and the identified opportunities and challenges formed specific codes which were subordinated to according themes. The authors agreed on generic terms for the themes, and assigned matching codes to them. For instance, one frequently occurring and relevant theme was ‘time’. The authors of this study subordinated the codes increased operation efficiencies, time reductions, early fault detection, concurrence of activities, high time effort to learn the handling of VR tools, and decreased number of prototypes produced to this generic theme, since they agreed that all of these codes are related to and have an impact on it. It should be mentioned that some codes are assigned to more than one theme, since they may be related to different ones. Table 7 provides an overview of the identified themes and the associated codes.

Table 7: Overview of the themes and their codes
Source: own illustration

<table>
<thead>
<tr>
<th>Themes</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications</td>
<td>Virtual Training, Virtual Prototyping, Virtual Manufacturing, Virtual Factory</td>
</tr>
<tr>
<td>Cost</td>
<td>cost reductions, early fault detection, increased operation efficiencies, impacts of mistakes are alleviated, high costs, mistakes in measurements</td>
</tr>
<tr>
<td>Time</td>
<td>increased operation efficiencies, time reductions, early fault detection, concurrence of activities, decreased number of prototypes produced, high time effort to learn the handling of VR tools</td>
</tr>
<tr>
<td>Environmental Sustainability</td>
<td>Decreased number of prototypes produced, decreased utilization and waste of materials, early fault detection</td>
</tr>
<tr>
<td>Communication</td>
<td>enhanced communication between globally distributed parties, enabled quick and profound understanding, seamless transfer of information, improved documentation of the PD process</td>
</tr>
<tr>
<td>Product</td>
<td>optimized product design features, early fault detection, insufficient fidelity of tactile feedback, risk of inaccurate imitation of the product</td>
</tr>
<tr>
<td>Process</td>
<td>improved processes, bespoke solutions for the PD process, enhanced assembly and production line capacities, increased flexibility, improved documentation of the PD process, optimized floor layout</td>
</tr>
<tr>
<td>Testing and Evaluation</td>
<td>evaluation of product and production decisions prior to the product realization, enhanced evaluation and control of systems</td>
</tr>
<tr>
<td>Employees</td>
<td>constant training for skilled employees, risk of sickness, encouraged participation and enthusiasm, impacts of mistakes are alleviated, risk of emotional or physical damage, risk of confusion between virtual and real environment, lack of technical knowledge of users</td>
</tr>
<tr>
<td>Customer</td>
<td>integration of VOC in the PD, tailored design to exact body shapes, risk of confusion between virtual and real environment, risk of sickness, lack of technical knowledge of users</td>
</tr>
<tr>
<td>Software</td>
<td>insufficient software capabilities, lack of data, incompatibility of systems</td>
</tr>
<tr>
<td>Hardware</td>
<td>uncomfortable devices</td>
</tr>
</tbody>
</table>
Evans (2018) states that one of the main obstacles with respect to qualitative interviews and thematic analyses is to represent the themes and patterns which were found in the data in an adequate manner. The author continues that sometimes it is possible to represent the data in a ‘pseudo quantitative’ way by using terms such as ‘the majority of respondents…’ or ‘most of them said…’ etc. (Evans, 2018) However, in the case of smaller samples, this kind of data representation is not very useful since it would not be of high relevance or validity (Braun & Clarke, 2006; Evans, 2018). Under such conditions, it would make more sense to provide the reader with profound explanations of the identified themes and to underline it by giving an exemplary quote from the interview (Evans, 2018). Further, and as already mentioned before, the aim of a thematic analysis is not to purely replicate and describe the themes which occurred in the data, but to interpret and make sense of them (Boyatzis, 1998; Braun & Clarke, 2006). In terms of this research study, the interview data were examined according to the coded themes which were defined on the basis of the literature review. More specifically, an in-depth investigation of the transcribed interviews was conducted by reading and re-reading every single passage of the interviews in order to recognize relevant codes and hence, to assign the passages to the according themes. It should be noted that the text passages in the interviews did not need to reproduce the exact wording of the defined codes in order to be assigned to a respective theme, but they needed to have the same meaning. Moreover, when a particular code, which was comprised in more than one theme, occurred in an interview passage, the researchers of this study decided based on the context to which theme or themes the passage should be assigned to.

Hence, the authors of this study went through the interviews in a step-by-step and back-and-forth procedure to search for all the defined themes and to reflect and interpret them. The identified themes were represented in the result chapter without attaching any meaning to them. In the discussion part of this study, the themes were interpreted and analyzed in more detail. The authors gave particular attention to the interpretation in the discussion chapter in order to reflect and make sense of the product developers’ opinions and attitudes towards VR in the PD process in fashion on the one hand, but to prevent prevailing generalizations on the other hand.

In general, qualitative research and related qualitative research methods can be problematic because its representativeness is limited with regard to the whole population (Bryman, 2012). For qualitative research, and hence for this study, strict empirical representativeness and quantitative measurement were less of an issue (Bryman, 2012; Frey, 2018); it was more about gaining an understanding of the context in which the research took place (Bryman, 2012) and to provide a starting point of research on which further research can be built. For this reason, the concerns of measurement validity and reliability did not play a major role in evaluating the quality of the research (Bryman, 2012). In fact, alternative criteria needed to be applied. Guba and Lincoln (1994) suggest two sets of criteria, ‘trustworthiness’ and ‘authenticity’, for evaluating qualitative research embedded in a paradigm of constructionism. However, Bryman (2012) states that the authenticity criteria have not gained much attention yet, and that their stress on a broader influence of research is contentious. Therefore, this study focused on the trustworthiness criteria.

Trustworthiness implies four distinct criteria and each is similar to a criterion in quantitative research:

1. ‘Credibility’ is the counterpart to internal validity and implies to assure the trustworthiness of the research findings and interpretations made. This credibility
assurance is often done by forwarding the research findings and interpretations to the relevant group of the data source (Guba, 1981). With regard to this study, credibility was ensured in a way that the three researchers of this study presented the written findings to the interviewees to double check whether their perceptions and meanings about VR in the PD of fashion were captured properly.

2. 'Transferability’ refers to external validity or generalizability and describes the level of analogy between two contexts and hence the applicability of research findings from one context to another (Guba, 1981). The decision about the transferability between two contexts is made by the reader (Morrow, 2005). Therefore, the researcher needs to provide “sufficient information about [...] the research context [...] to enable the reader to decide how the findings may transfer.” (Morrow, 2005, p. 252) However, qualitative research typically examines a small sample of individuals with particular characteristics and therefore, the research findings usually relate to a unique context and are not generalizable in its common sense (Bryman, 2012; Morrow, 2005). In order to enable the reader to decide about the transferability of this study, the researchers provided detailed insights about the methodological procedure and thus about the overall research context.

3. 'Dependability’ parallels reliability and concerns the consistency of the qualitative study (Guba, 1981). Therefore, the procedure of getting to the final results should be as clear-cut and replicable as possible (Morrow, 2005). This can be achieved by cautiously monitoring the emerging research findings and by applying an auditing method which assures that all steps of the research process are documented (Bryman, 2012; Morrow, 2005). The documentation can then be forwarded to a peer-examiner to check the process against its consistency (Morrow, 2005). With respect to this research study, consistency was maintained through keeping records of the overall research procedure and a constant exchange with the researchers’ supervisor. However, the dependability of this study was somewhat limited due to the inexperience of the authors in conducting semi-structured interviews. For this reason, the first interview only took 22 minutes whereas the other four interviews lasted between 35 to 52 minutes. Moreover, since the theoretical stance of this study is largely grounded in constructionism, it should be mentioned that the captured reality refers to how the interviewees perceived VR in the PD process in the fashion industry to this specific point in time. Hence, by conducting the same study at some undetermined point in the future, the findings of the study could be totally different “because of evolving insights and sensitivities” (Guba, 1981, p. 81).

4. 'Confirmability’, as the last sub-criterion of trustworthiness, resembles objectivity and deals with assuring that the researcher has conducted the study in all conscience and avoids to express his or her own personal opinions and tendencies as much as possible, under the aspect that full objectivity is not feasible in social research (Bryman, 2012). The confirmability of the research refers to the neutrality of the data (Guba, 1981) and the researcher needs to link the data, analysis, and the results in a way that the reader will approve the appropriateness of the findings (Morrow, 2005). As for dependability, Morrow (2005) suggests to make use of an auditing approach to account for the confirmability of the data and to manage subjectivity. By displaying and recording every single step of the approach of this research, and by discussing it with the researchers’ supervisor and different master students, the researchers attempted to maintain the study as objective as possible.
4 Results

This chapter presents the results of the interviews with regard to the previously defined themes and codes and is divided into three sub-chapters. The first covers the answers about product development in the fashion industry and Virtual Reality in general. The second part relates to the four areas of application of Virtual Reality in the product development in the fashion industry. The last part provides an overview of the interviewees’ answers regarding the possible opportunities and challenges when implementing VR in the PD. Last but not least, a table summarizes which opportunities or challenges the interviewees were referring to.

4.1 Virtual Reality in the Product Development

In the beginning of the interviews, the interviewees were asked general questions about their definition of product development as well as their work experience within the department. This showed that interviewee A worked for three and a half years in the PD, B and C for one year, D provided work experience of two years in the area, whereas E has worked in PD for the longest period of four and a half years. It became obvious that product development comprises similar tasks in the companies of the interviewees. They defined it as the creation of the product by translating design concepts into technical details, serving as a touch point between suppliers, manufacturers, and designers, organizing fittings, and quality testings in order to develop a physical product that the consumer can use. Interviewee E added that a product developer’s tasks start with the first briefing, over the final sales samples in the showroom to the final production of the product, until it is on the shop floor. In this context, B said that “as a product developer, you really have to be at every stage of the product […] from when the design plans come in, until the end of production.”

In the second part of the interview, all interviewees were asked about their individual definition and perception of VR. Currently, everyone described VR as abstract and futuristic and mentioned difficulties in completely understanding how it looks like and works. Interviewee C pictured it as “working with a virtual product simulation instead of a physical sample or prototype.” Interviewee D and E referred to VR as an enabling tool to see and feel an environment without actually being there, and that allows users to interact with this environment without interfering with the real world. Additionally, D added “I think it is more of an entertainment rather than a professional application.” D reasoned that VR equipment are not appropriate for when dealing with a sales or concept meeting. It showed that interviewees A, B, D, and E have tried VR once in their personal life. Companies 1, 3, and 4 are currently experimenting with and testing VR devices but have not established or implemented any concrete applications.

4.2 Areas of Application

Applications

Virtual Training

This area was named as useful by interviewee A, B, and E with the restriction that it is only important to some areas such as the pattern making or training of the sales staff on how to present the developed collections. For C, Virtual Training appeared to be “too futuristic […] and difficult to imagine” and the least important. D could not see any benefits compared to a simple Skype call as well as that it would be more suitable “for example for firefighters for training in a dangerous situation.”
**Virtual Prototyping**

All interviewees agreed on the importance of Virtual Prototyping for the PD in the fashion industry in order to achieve cost and time reductions as well as ease the product development process. Further, they declared VP to be the most relevant of all four areas. Interviewee D claimed it will be the future of product development. Moreover, interviewee A argued that this refers only to “the same styles but in a different color, or when you need to replace a print on a shirt.” Insufficient technologies were mentioned as the reason for not implementing VR on completely new products and collections.

**Virtual Manufacturing**

A, B, and E pointed out the relevance of Virtual Manufacturing to drive the speed of production. However, the latter remarked that this requires the suppliers to work with VR as well, which creates a challenge for companies today. Moreover, the interviewees saw less of a relevance in the implementation of VM when compared to VP and VT. Interviewee D pointed out the importance of VM in general, but not relating to the product development in the interviewee’s company as it would be in the responsibility of sourcing sites and suppliers. Besides, D noted that this would be especially challenging for suppliers in Asia. Interviewee C could not make an evaluation due to a lack of knowledge and experience in this area.

**Virtual Factory**

For interviewee E, this area came along with VM and ranked them as equally important. A and B did not regard it as beneficial due to accuracy problems and barriers in the implementation. B mentioned “I don’t think it is accurate enough or manageable yet, because […] big factories […] would be very disorganized.” Interviewee D acknowledged the relevance for the fashion industry as a whole, but not regarding the product development in the interviewee’s company. One reason for that mentioned by the interviewee was “the facility of product development is an office or a desk”. Additionally, Interviewee C could not build an opinion about the area.

### 4.3 Opportunities and Challenges

#### Cost

All consulted interviewees mentioned *cost reductions* as one of the main benefits of VR in the product development for the fashion industry. In this regard, E explained “costs for prototypes are quite high and adapting it always costs money as well” for which reason the reduced number of prototypes would lead to a decrease in costs. Interviewees A and D emphasized that costs decrease because less material is needed to build the prototypes. Moreover, the former added that these cost reductions can only be achieved when VR is implemented at the right stages of the product development process and without any mistakes. In addition to that, interviewee C claimed that costs can only decrease over the long term. Lastly, D stated that less employees needed are another reason for lower costs.

To go on, *high costs* for the implementation and equipment of VR were declared as the biggest challenge in the product development according to A, B, C, and E. The latter stressed “in the beginning, technology and the implementation cost a lot of money [as well as] until everybody is onboard”. The interviewee named this as a reason why the interviewee’s company has not implemented VR yet.

The interviewees did not refer to *early fault detection, increased operation efficiencies, impacts of mistakes are alleviated, and mistakes in measurements.*
Time

*Increased operation efficiencies* can be reached through an improved workflow with suppliers as reported by interviewee A. Interviewee B acknowledged the technology which makes the PD cycle more efficient and accurate as reasons for efficiency enhancement. D related to time improvements from an operation standpoint which, in turn, increases productivity.

Furthermore, *time reductions* were emphasized as another key opportunity by all five interviewees. In this context, D and E agreed on a decrease of development time, decision making time, shipping time, production time, and time for the creation process as a whole by enabling to react faster to the consumer. According to A, time reductions were achieved primarily in the shipping of samples and the making of decisions. B saw “the biggest time saver” in communication in the sense of that “VR is like a solution to have a platform where both parties understand each other […] without a wall between them”. Interviewee C mentioned “if you do changes on the product, you can see it immediately on the virtual product instead of waiting three or four weeks until you receive it from the factory, so the development process would be a lot faster.” Additionally, E described:

> When the prototype is coming back from Asia or [...] Italy, then we are looking at it, we are fitting it, we are making comments on it, packing it, sending it back. The suppliers have to adapt it, and send this prototype again back to us. We are fitting it again, we are changing it, sending it back, and you lost at least four weeks. With Virtual Reality it could be all done in six hours.

Nevertheless, A and C were convinced that it takes a *high time effort to learn the handling of VR tools* as well as to adapt to the new process. In this regard, C stated:

> I guess the biggest part is learning to use the tool because I think that's not so easy. So, I don't know if one of our developers could be able to use this kind of tool or if you actually need someone who studied informatics.

The interviewees did not refer to *early fault detection, concurrence of activities, and decreased number of prototypes produced*.

Environmental Sustainability

In this topic, the interviewees B, C, and E pointed out that the *number of prototypes produced decreases* when using VR in the product development. They also mentioned that reduced shipping would reduce the environmental impact. In addition, B saw this as an opportunity for companies to strengthen their sustainability profile and use it as a competitive advantage on the market.

Further, C and D brought up the *decreased utilization and waste of materials* which positively influences the environment since interviewee C claimed “for example in footwear, the highest […] environmental impact occurs during manufacturing, so also including samples”. In this regard, A and E saw this point as contradicting as the material used for building the VR equipment had to be considered as well. E added “the question is what is cleaner in the long term”.

The interviewees did not refer to *early fault detection*.

Communication

B, C, and E saw an opportunity in the *enhanced communication between globally distributed parties* in terms of that time can be reduced, direct feedback is possible as well as it removes
walls between product developers and manufacturers by providing a common platform. Interviewee C argued “you have to deal with different suppliers from all over the world and if they were all using the same systems, the products would be of higher quality”. In this connection, A pointed out the risk of behaving differently in a virtual room than in the real world as well as mentioned problems with cultural differences. Further, A spoke of “it will never replace the proper communication [...] you have with the suppliers even though you can meet in virtual rooms [...] because the cultural differences are so visible in product development”.

Furthermore, interviewee B spoke of VR as a tool to show the opposing side, such as suppliers, the exact concern as well as exchange opinions. Therefore, it is allocated to the category of enabling a quick and profound understanding. However, B also argued that due to the globally fragmented fashion industry and since many suppliers are located in Asia, language barriers are often high and “there are often problems with communicating the right product [to the suppliers].”

Besides, D named the seamless transfer of information as challenging due to the high number of suppliers involved.

The interviewees did not refer to improved documentation of the PD process.

**Product**

In terms of optimized product design features, A and C acknowledged a better overview that directly depicts changes supporting the decision making. C further added that the difference between a real and virtual product is basically not observable. Moreover, interviewee E mentioned “you can easily adjust products [...], turn it around, or swap from a button closure to a zip closure.” Similar to that, D stated that VR “allows the application of 3D products into the real world.” In addition, interviewee B argued that the application of VR in the product development reduces the risk of a misunderstanding with suppliers regarding the design features of the product.

However, the insufficient fidelity of tactile feedback was highlighted by the interviewees A and E. According to this, A advanced the view of the product development as a sensory field that requires to feel and grasp the product; “you need to touch it, you need to see inside the garment, you need the comfort confirmation of a fitting model.” E argued that VR would be applicable for basic products but not for high-quality products such as suits, which require a high precision in cut and material. As an example, the interviewee described: “Almost everybody can imagine it when you are talking about a French Terry […], but if I am talking about a Super 150 with a linen part, it could get more difficult”. E further argued:

> In the future, [...] [luxury brands] will not use Virtual Reality for their products or collections, because they still want to work on design because it is a handcraft. You are building something with a lot of emotions behind it.

Additionally, these points also relate to the risk of an inaccurate imitation of the product. Interviewee B said that the VR image of a product is not as accurate as in the real world and added “you already see problems occurring with 3D technologies”. C claimed that it is a real product that is sold and not a virtual one. In this context, D mentioned differences between reality and Virtual Reality in details such as textures, materials, colors, or lighting which are difficult to overcome.
The interviewees did not refer to *early fault detection.*

**Process**

One of the main opportunities mentioned when implementing VR in the PD was *improved processes.* This possibility was claimed by all of the interviewees. A argued that the implementation could speed up the process and could improve the workflow, depending on the current system. B further stated that the implementation of VR in the PD can lower the effort in the process. In addition, interviewees A, B, and C emphasized that the whole process would be improved in a sense that it is faster and cheaper because the number of physical samples is reduced as well as waiting times. C additionally said that the speed and cost reductions are also pushed by being able to do everything in one tool and by reducing the needed communication. “I mean you can do everything with one tool, right? So everything that you change will happen in this one simulation. You don’t have all this factory communication.” With regards to process improvements, D argued: “If you are virtualizing […] the creation process, it cuts down the decision making time, cuts down the production time, cuts down the creation process as a whole.” E further pointed out that the process is improved through VR in a way that it is possible to link different supply chain partners to each other. With regards to improved processes C stated that “you need to overthink your timelines, the meeting points, which meetings do we need to hold if we have Virtual Reality.” Another important issue mentioned by interviewee D was the need to consider where to apply workload.

The literature highlighted the opportunity to allow *bespoke solutions for the PD process.* With regard to this opportunity, E pointed out the benefit of products being easily adjusted and making the product development cycle easier. E further said that the product developers can directly interfere in the development of the styles and the designers and developers can exchange ideas in both directions in a more visual way.

The *increased flexibility* was discussed by interviewees D and E, who both considered the application of VR in the product development as an opportunity regarding this issue. D argued that “real time flexibility and creation would be the biggest opportunity.” According to D, this is especially beneficial when it comes to real time fulfillment of customer requirements.

The interviewees did not refer to *enhanced assembly and production line capacities,* *improved documentation of the PD process,* and *optimized floor layout.*

**Testing and Evaluation**

In terms of the *evaluation of product and production decisions prior to the product realization,* interviewee A said that the evaluation of products will still need to be based on fitting models. Further, A stated that this would never change, because the feedback from a fitting model is needed. “I think it will never replace a proper fitting with a fitting model where you can really touch it [and] feel it.” C also pointed out that there is still the need of a real sample in this step of the PD. Interviewee E argued that the haptic feedback is not necessary for all products. Thus, the interviewee concluded that products which do not need this kind of feedback are suitable for the implementation of VR in the PD. In the interview, E named basic products like jersey shirts as an example, because the feeling of the fabric is known; “I think you need […], especially for products like suits, real prototypes and samples because we need to see how the quality is falling, how it feels like and all that.”

The interviewees did not refer to *enhanced evaluation and control of systems.*
Employees

The opportunity to encourage participation and enthusiasm through the application of VR in the PD was discussed by considering various aspects. Firstly, A pointed out that the implementation of such a technology requires quick learning skills and willingness to adapt to the change. According to A, these criteria would mostly apply to younger generations by saying “I think, when you're young or [...] still flexible then you can adapt and when you're a quick learner [...] and you're open for change.” Interviewee D and E mentioned this challenge, but kept it more general. E further referred to it as an obstacle related to culture. “A cultural change is way bigger and takes much more time than just a technology change.” E further stated that technological change is for some companies connected to giving up a handicraft. Therefore, E concluded that the implementation of VR in the PD will not be relevant for all fashion companies:

In the future, [...] [luxury brands] will not use Virtual Reality for their products or collections, because they still want to work on design because it is a handcraft. You are building something with a lot of emotions behind it.

With regards to participation and enthusiasm, A further mentioned the need for top management commitment. In addition, B stressed the importance of being on the same page when implementing such a technology. “But you have to make sure that when you use VR that you're really on the same page. Because if you're not […], then it's going to be [a] disaster.” In this context, D highlighted the importance of giving information about the execution of the implementation process.

In terms of the opportunity to alleviate mistakes, interviewee E highlighted that it is necessary to allow mistakes in the beginning phase of the implementation of VR in the PD. “Allow mistakes because [it] will happen that people are doing mistakes and that costs money.”

Concerning the lack of technical knowledge of users, all the interviewees mentioned the need to acquire knowledge about the use of the technology. Interviewee B pointed out that the product developers are lacking experience in VR. This viewpoint was shared by E, who stated that getting experience and developing soft and hard skills are essential:

So we need to know exactly every click, or whatever it would be in this program. On the other hand, I guess, I need much more capabilities of how this product would really feel […]. I really need to get experience.

The interviewees did not refer to constant training for skilled employees, risk of sickness, risk of confusion between virtual and real environment, and risk of emotional or physical damage.

Customer

Regarding the integration of VOC in the PD, interviewee D acknowledged several opportunities. Firstly, D said that it is beneficial for the customer if the VR technology would enable to see the clothes from a customer perspective, just as changing the colors of the style would be very easy and quick for the customer. Secondly, D saw the opportunity for live design in the implementation of VR in the PD because it allows the consumer full control in terms of the availability of the products and personalization:

It'd be useful in the sense [of] that if you could see what you are wearing from your first person perspective. I'd be able to change that instantaneously so if I was wearing a grey jumper right now and I wanted to see what it is like in red and blue. That allows the consumer to have full control. Not only on
what products are available but also allow the consumer to personalize the products that they have. I guess you could call it live design in a way.

Thirdly, D argued that the customer feedback could be considered and the customers could choose what they want which would consequently lead to increased sales and satisfied customers. Lastly, interviewee D said that the customers are happier because their needs are fulfilled before the product hype is over. In addition, E mentioned that product developers can get a more direct customer feedback through the implementation of VR in the PD. “Actually what would be a big advantage of Virtual Reality, that you can get direct customer feedback.”

Regarding tailored design to exact body shapes, A emphasized that VR technologies give the customer more choices regarding the fit and adaptable styles.

B and C mentioned the challenges of VR in the PD for the customer which can be assigned to lack of technical knowledge of users. B was concerned with VR technology as being too much for the customer.

The interviewees did not refer to risk of confusion between virtual and real environment and risk of sickness.

Software
The concerns about insufficient software capabilities were only partly shared by the interviewees. Interviewee A stated that the software is very close to reality regarding optical elements. C supported this by stating that it is not possible to tell the difference between the real and virtual product. B on the other side argued that the software is sometimes not accurate enough. According to interviewee D, the software is not capable to make the virtual product look like the real product due to factors like light:

A big issue we have at the moment is the fact that we would use computer generated images or virtual images to show clients what they could potentially buy. But in reality the parts at the end come out looking very different.

Another big issue, pointed out by A, was the feel of the product. “You always need the feel of the fabric which is hard to really show through Virtual Reality.” Interviewee D was concerned about possible errors in the software. In D’s opinion, the software needs to be foolproof because an error in the software would lead to a lack of trust in the technology:

If you apply a system like this to a business function and there is an error, the trust in that system is lost instantaneously. So it would have to be foolproof.

Further, B emphasized that it would be the best that there were no errors at all and that, in case of an error, the product developers knew how to fix it. With regard to the insufficient software capabilities, C pointed out that the software might improve and change so fast that the company will have a hard time keeping up with the development. B further claimed that especially in small companies, the system is not developed enough and that such companies do not have the ability, both system and software wise, to implement VR.

With regard to the incompatibility of systems B mentioned that there is a big gap between the technological development of the suppliers and the retailers. E pointed out that the PD can get very difficult if the supplier is not working with these technologies. E also mentioned the possibility to link different supply chain partners.
The interviewees did not refer to lack of data.

**Hardware**

With regard to the uncomfortable devices, interviewee B was concerned “that people feel like it's too much of work to put the whole thing on and to have the right settings.” In addition, D pointed out that the need to wear the VR glasses “is not a sensible application to use in sales meetings and concept meetings.”

Table 8 gives an overview of the themes and relating codes, which were mentioned by the respective interviewees. If none of the interviewees referred to the code (opportunity/challenge) the field was marked with a hyphen (-).

**Table 8: Opportunities and challenges covered by the interviewees**

Source: own illustration

<table>
<thead>
<tr>
<th>Topic</th>
<th>Opportunity/ Challenge</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>Cost reductions</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td></td>
<td>Early fault detection</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Increased operation efficiencies</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Impacts of mistakes are alleviated</td>
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<td>High costs</td>
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<td>Mistakes in measurements</td>
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<td>Increased operation efficiencies</td>
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<td>Decreased number of prototypes produced</td>
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<td><strong>Testing and evaluation</strong></td>
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The respondents stated that there will always be challenges when implementing new technologies like VR. E saw the future of PD partly influenced by the VR technology; “so, it will change product development partwise. But I guess product development in general changes because the full fashion industry will change.”

Four interviewees concluded that in the future, the opportunities and benefits of such technologies will outweigh the challenges. With regard to the balance of opportunities and challenges, interviewee A stated:

I think right now it's really like even and balanced. I mean they give some benefits but yeah it takes so much effort on the same time. […] If these technologies get further improved maybe the benefits overweight all the struggle you have with it.

Interviewee B argued:

There will always be challenges, but I think they would outweigh […]. Basically anything could be possible these days, and especially in those fields. I think if you invest enough time and money in it, then of course it would outweigh and it would be very beneficial.

Furthermore, interviewee C emphasized:

I think there are so many positive points but also, I mean it would mean a change for myself, so change always means that you're kind of afraid and you need to adapt to something new. But, yes, I think it's the future, though.

Interviewee D also said that the challenges currently outweigh the opportunities, but D further highlighted that the technology could be implemented in ways that we are not able to think of yet:

Currently yes, but that doesn't mean in five years time that we, I don't know, develop quantum processing for computers and we can apply software programs very, very easily and adapt them in a flexible [way], which will […] open further doors for applications such as Virtual Reality that we just don't know about currently.
5 Discussion
This chapter follows the structure of the results and is thus divided into the sub-chapters Virtual Reality in the product development, areas of application, and opportunities and challenges. In order to find an answer to the research questions, the discussion aims to reflect upon and interpret the interviewees’ opinions and the findings from the literature regarding the application areas of VR in the PD in the fashion industry. Accordingly, the opportunities and challenges of VR in the PD in fashion are discussed.

5.1 Virtual Reality in the Product Development
As the results show, there is a general skepticism towards VR among the interviewees. Everyone had some comprehension and an opinion about what Virtual Reality comprises of, but generally described it as difficult to imagine and intangible. As none of the interviewees has intensively worked with VR in the product development, they took a critical position towards the topic (see chapter 4). This could be related to the novelty of VR in the product development in the fashion industry as well as the challenges it implies. Furthermore, the interviewees doubted the current state of technology and questioned its feasibility and manageability in fashion companies, especially at the supplier level.

5.2 Areas of Application
The literature identified four different areas of application for VR in the product development in manufacturing industries: Virtual Training, Virtual Prototyping, Virtual Manufacturing, and Virtual Factory (see chapter 2.2.3). Therefore, the interviewees were asked about their views on which of these four areas would also apply to the fashion industry.

Virtual Training
Three of the interviewees saw some opportunities in VT for the fashion industry, specifically for the pattern makers or for training the sales staff on collections. The two other interviewees had an incredulous view about it by criticizing the potential benefits compared to conventional training methods today (see chapter 4.2). As described in the literature, a well trained product development team is important to create high quality products and to optimize production and sales processes (see chapter 2.1.2). Therefore, VT bears a lot of advantages such as it encourages participation and enthusiasm, enables quick and profound understanding, and increases flexibility (see chapter 2.2.3). Since the fashion industry is known to be globally fragmented, VT is useful in terms of bringing people together that are physically not at the same place in order to save time and costs for trainings. Nonetheless, the risk of sickness has to be considered, in particular for employees who do not use the devices regularly (see chapter 2.2.3). In addition, as noticed by one of the interviewees, VT would be beneficial when employees are put in danger in training situations which does generally not apply to the fashion industry (see chapter 4.2).

According to the literature and the responses of the interviewees, there are both opportunities and challenges for implementing VT in the product development in the fashion industry. Therefore, it can be assumed that if the potential training candidates are situated in different locations or are exposed to a dangerous training environment, VT can be beneficial. However, it can be concluded that the necessity of providing Virtual Training has to be assessed depending on the risk to the employees, which is usually not the case in the fashion industry.
For this reason, it should be evaluated if the economic expenses required for the VT equipment are lower than the ones needed for travel expenses to bring the employees to one location. Moreover, VT was assessed by the interviewees as an additional application area when VR is already implemented for other purposes.

**Virtual Prototyping**

VP was seen by all interviewees as the most relevant and promising area for the fashion industry. Since the pressure for fashion companies regarding decreasing product life cycles and quickly changing customer needs grows (see chapter 2.1.3), time reductions in the product development process are strongly needed. Further, one interviewee claimed that the fashion industry requires a high number of prototypes per collection which are quite intensive in time and money (see chapter 4.2). In this regard, the literature mentioned that the product development consists of many iterative steps including building several prototypes, testing different versions, and revising the design respectively in order to reduce market uncertainty (see chapter 2.1.1). Moreover, the product development process entails many different stages to determine and evaluate raw materials and fabrics and to calculate resulting costs (see chapter 2.1.2). Therefore, virtual prototypes promise to not only enhance the product development from a time perspective, but also when it comes to costs (see chapter 2.2.3). Moreover, the literature as well as four of the interviewees pointed out the positive impacts on the environment in terms of having less prototypes, resulting in a decrease of materials used and a reduction in shipping (see chapter 4.2; chapter 4.3). In addition, VP is beneficial for offering customized products by integrating the VOC in the development process (see chapter 2.2.3) which is one of the decisive success factors when developing new products (see chapter 2.1.2). In contrast, one interviewee argued that VP is only useful to some extent, claiming for color changes or small adaptations but not for new product development (see chapter 4.2). The literature further identified barriers relating to insufficient software capabilities and technologies as well as the risk of inaccurate imitation of the product and an insufficient fidelity of the tactile feedback which was confirmed by the interviewees. In this context, they emphasized the importance of touch and feel in the fashion industry. One interviewee specifically spoke of fashion as a handicraft which is associated with a lot of emotions and which gets lost by replacing it with VR. Thus, the interviewee advanced the view of using VP for basic products rather than high-quality products (see chapter 4.2; chapter 4.3).

By considering all the facts mentioned above, it is emphasized that VP can be seen as the most relevant area for the fashion industry. Since the number of prototypes in the fashion industry is high, cost and time reductions can be tremendous, especially from a long range view. Nevertheless, the product development in the fashion industry involves emotions and the proximity to the product. For this reason, it could be suggested to use VP for simple and basic products leading to high time and cost reductions. For high-fashion and high-quality products, the haptic feeling of the materials is crucial.

**Virtual Manufacturing**

Three of the interviewees acknowledged VM as an important area for establishing VR in a fashion company. However, they ranked it behind VP and VT which does not say it is less important, but more difficult to implement (see chapter 4.2) since the fashion industry is known to be globally distributed and the production part is often outsourced to countries in Asia (see chapter 2.1.3). In all companies of the interviewees, the production was not part of their daily tasks, but rather the communication with suppliers. In this regard, VM would require the suppliers to use VR techniques which pose a big challenge to the realization of VM as there is a lack of knowledge and experience in this area and often the necessary money
for the equipment is not provided. Another interviewee could not give any thoughts or
opinions to the topic (see chapter 4.2) which emphasizes the complexity of VR in relation to
manufacturing processes. The literature stressed the importance of a trial production run
throughout the PD process in order to assess the manufacturing time, throughput, and costs,
amd to change the manufacturing method if necessary (see chapter 2.1.2). In this context, VM
provides a list of benefits including, amongst others, the concurrence of activities, the
evaluation and control of systems, an early fault detection as well as time and cost reductions
(see chapter 2.2.3).

According to the product development process in the literature, VM would be a beneficial
application (see chapter 2.2.3). However, the interviewees did not see the manufacturing as
part of their responsibility and further believed that an implementation to this day would not
be feasible due to the globally fragmented supply chain as well as the unpreparedness and
lacking capabilities of suppliers (see chapter 4.2). Hence, it can be interpreted that from a
holistic perspective, which assigns the manufacturing task to the product development, VM
may be a promising area of application for the future, provided that the aforementioned
supplier issues are solved. Nevertheless, at the present time, VM is not perceived as a viable
application for the product development in the fashion industry by the interviewees.

Virtual Factory
The opinions about VF as shared by the interviewees resembled closely to VM, however they
ranked its relevance and application slightly behind. Despite this, only one interviewee
emphasized its importance by indicating its connection to Virtual Manufacturing in order to
enhance speed in the production (see chapter 4.2). In the fashion industry, the manufacturing
part in the product development process is usually outsourced to globally distributed suppliers
(see chapter 2.1.3) which would imply that VF lies in their responsibility. This was confirmed
by one of the interviewees in describing the facility of PD as an office instead of a factory.
Moreover, the interviewees spoke of the difficulty and complexity of implementing VF,
especially at big factories (see chapter 4.2). On the other hand, the literature highlighted the
importance to test and, if required, rearrange and adapt the final production facilities during
the ‘trial’ stage of the product development (see chapter 2.1.2). In this context, VF can enable
the optimization of the floor layout, enhance concurrence of activities, avoid bottlenecks,
provide a seamless transfer of information, increase operational efficiencies, facilitate
communication between globally distributed parties as well as achieve overall cost and time
reductions (see chapter 2.2.3).

Thus, the findings of the literature as well as the interviewees’ responses demonstrate how
useful VF is to the fashion industry, but also show that factories and systems are not ready yet
for an implementation of VR. This is confirmed by the challenges identified in the literature
such as insufficient software capabilities and that mistakes and miscalculations in
measurements and modeling imply tremendous costs (see chapter 2.2.3). Moreover, the
interviewees recognized its importance for the fashion industry, but not for the product
development. In this regard, it is interpreted that a proper implementation has to be ensured in
order to avoid consequential costs due to unpreparedness and infeasibility of systems and
suppliers.

By examining the literature and questioning the interviewees, it can be concluded that Virtual
Prototyping might represent a great opportunity for the product development in the fashion
industry due to the high number of prototypes needed and produced, the high shipping and
materials costs, and the time factor in the product development process. Based on the
interviewees’ responses, it can further be assumed that this area provides the most achievements to a fashion company compared to the others. Nonetheless, the areas of VT, VM, and VF can also be applied to the fashion industry offering a number of additional benefits. In this regard, the necessity and justifiability have to be clarified in terms of VT just as suppliers need the capabilities and commitment to establish VR in their procedures regarding VM and VF.

5.3 Opportunities and Challenges

Cost

Cost reductions

All interviewees mentioned cost reductions as one of the main opportunities of VR in the product development. In this regard, they primarily referred to the reduced costs for prototypes and the required material since the number of prototypes can be overall decreased. Additionally, the interviewees acknowledged an enhanced and accelerated communication between the actors along the supply chain (see chapter 4.3). Similarly, the literature described cost savings for virtual prototypes compared to physical prototypes which are currently used in the fashion industry (see chapter 2.2.3). The example from the automotive industry shows that one of the main motivations to apply VR in the product development relates to the reduction of costs (see chapter 1.1).

As claimed by the interviewees, the fashion industry produces a high number of prototypes, for which reason it is believed that for prototyping cost reductions could be significant in the long term. According to the literature, this applies not only to VP, but to the other areas as well. As described in chapter 2.2.3, the application of VR enables to simulate processes and products allowing the detection of mistakes and weak points before they occur, which, in turn, saves costs. On the other hand, the expenses needed for the equipment of VR, its implementation and the adaption of systems, employees and the company to the new technology has to be considered as well. This challenge is discussed separately in the next section. However, the literature and interviewees are convinced that despite the possibly high investments in the launching phase, VR can reduce costs in the long term by enhancing a company’s profitability.

High costs

Four of the interviewees saw high investment costs as one of the biggest challenges in implementing VR in the product development. Beyond that, one of them explained this as the main reason why the interviewee’s company is not using VR in the PD. According to this interviewee, this does not only include expenses for the VR equipment, but also the necessary adaptations in systems and software as well as the training of employees (see chapter 4.3). On the one hand, the literature also specified the high investments as a general challenge for implementing Virtual Reality in a company. On the other hand, it repetitively mentioned cost reductions in all four areas and relating to the use of VR overall (see chapter 2.2.4).

Therefore, it has to be acknowledged that VR is a cost intensive endeavor which requires financial, time-based and employee-based resources. Further, it is claimed by the interviewees that the high costs act as a deterrent to many fashion companies. Nevertheless, long term cost reductions especially regarding VP are believed to compensate the initial investment in the technology.
**Time**

*Increased operation efficiencies*

One interviewee described an improved workflow with suppliers, whereas another interviewee referred to a more efficient and accurate product development cycle enabled by VR. The latter explicitly spoke of operational improvements that enhance productivity in the product development (see chapter 4.3). The literature identified an overall increase of operation efficiencies in the areas of VT, VP, VM, and VF. These improvements relate to time and cost reductions in order to enhance operations and the product development as a whole (see chapter 2.2.3).

On these grounds, it can be interpreted that increased operation efficiencies are an opportunity of VR in the PD in the fashion industry. Hence, it does not only enable advancements in time, but also in costs. Further, one of the interviewees held the opinion that cost and time are the two factors that drive the business next to quality (see chapter 4.3). Accordingly, this could mean that improvements in these two areas can put a company in a better position on the market, financially and competitively.

*Time reductions*

Next to cost reductions, also time reductions were claimed to be among the main opportunities of VR in the PD by all five interviewees. Two of them specified that it decreases time for development, decision making, shipping, and production. Thus, they concluded that a quicker response to customer demand is possible. Furthermore, one interviewee referred to time savings in the shipping of prototypes, whereas another one saw time improvements primarily in the communication. Lastly, it was described that the whole product development process can be accelerated with VR (see chapter 4.3). The literature mentioned ‘speed’ as a critical success factor of the product development in order to reduce development cycle time and to generate a competitive advantage (see chapter 2.1.1). Therefore, the application of VR can be seen as a noticeable opportunity when it comes to the factor of time. This mainly relates to the prototype production and communication (see chapter 2.2.3).

In this regard, one can assume that time reductions are a key advantage of VR in the product development. With respect to the short product life cycles and high competition in the fashion industry (see chapter 2.1.3), a time advantage can be the decisive factor for a company’s success. Therefore, time reductions implied by VR in the PD could provide a competitive advantage for a fashion company.

*High time effort to learn the handling of VR tools*

Two of the interviewees brought up the difficulty and effort to learn the use of VR equipment. One of them also scrutinized if the skills of a product developer would be sufficient to be able to handle VR tools (see chapter 4.3). For VP, the literature depicted a lack of technical knowledge of the users which brings forth a high time effort for learning the use of the devices. Moreover, it is said that if the handling is not learned properly, the use of VR becomes inefficient (see chapter 2.2.3).

Accordingly, the findings of the literature and the interviews reveal that there is a challenge in learning the handling of VR tools and that conquering this challenge needs a lot of time and effort. Moreover, the interviewees agreed that a product developer using VR needs different skills, like a higher technical affinity than a product developer not using VR (see chapter 4.3). However, it can be assumed that the invested time in training for VR is reasonable compared to the time reductions that can be achieved.
Environmental Sustainability

*Decreased number of prototypes produced*

According to three of the interviewees, the use of VR reduces the number of prototypes produced. Beyond this, they expressed the implication of less shipping which, in turn, decreases the environmental impact of a company. One interviewee reasoned this to be a great chance for companies to enhance their sustainability performance which can serve as a competitive advantage on the market (see chapter 4.3). By examining the literature, it came up that the number of prototypes can be minimized in VP and VM. Regarding VP, physical prototypes are replaced by virtual prototypes implicating that no real prototypes actually get into production. With VM comprising the simulation of products and production processes, amongst others the number of needed prototypes can be cut down in order to enhance productivity (see chapter 2.2.3).

To this effect, the literature and interviewees see the positive effect on the environment by using VR in the PD in terms of reducing the number of prototypes produced. One interviewee especially emphasized how this impact could be used by the company referring to their sustainability profile which therefore provides a great opportunity for fashion companies.

*Decreased utilization and waste of materials*

Two interviewees discussed the reduced use of material and resources in connection to less prototypes produced which both cut down the negative environmental impact in the product development (see chapter 4.3). This is supported by the literature emphasizing the importance to reduce the waste of resources for a successful product development (see chapter 2.1.1). In the literature of VM, the decreased material use related to the possibility of simulating products and conforming manufacturing processes. As stated in VP, by creating virtual prototypes instead of physical prototypes, material can be saved as well as waste of material is minimized (see chapter 2.2.3).

Both the interviewed product developers and the examined literature point to the decreasing utilization of materials providing an important opportunity of the PD in fashion companies in matters of environmental sustainability. By taking into account that the highest environmental impact occurs in the manufacturing phase, according to one interviewee, VR could induce a great advancement for the company.

Communication

*Enhanced communication between globally distributed parties*

Three interviewees brought up how VR enables the communication between globally distributed parties. They further mentioned that by creating a digital platform, direct feedback and visual exchange is possible, whereas the communication is immensely accelerated. In this context, one of them referred to the globally fragmented supply chain in the fashion industry for which this opportunity of VR would be specifically helpful (see chapter 4.3). The literature regarded the product development as a multidisciplinary process involving different parties in an organization and thus, requiring close interaction and the sharing of information. Since most companies nowadays operate on a global level, communication between distributed parties becomes vital (see chapter 2.1.2; chapter 2.1.3). Moreover, it stated the importance of VR as a communication tool. These opportunities for communication apply to all areas: VT, VP, VM, and VF (see chapter 2.2.4). However, one interviewee was convinced that VR cannot replace actual face-to-face communication since the users’ behavior in virtual rooms differs to the reality. The interviewee further spoke of cultural differences that cannot be overcome through Virtual Reality (see chapter 4.3).
On the one hand, the affirmation of the literature concerning that the communication between globally distributed parties is a key opportunity in implementing VR in the product development which was supported by three interviewees. On the other hand, cultural differences and behavior modifications should be taken into consideration.

**Enabled quick and profound understanding**

According to one interviewee, VR can be used as a tool to exchange opinions that helps to make the opposing part understand one’s exact concerns. Nonetheless, the interviewee saw challenges in language barriers due to the globally fragmented supply chains of the fashion industry. Thus, to the comprehension of this interviewee, VR can support a quick and profound understanding through the facilitated communication, but obstacles such as language barriers have to be considered (see chapter 4.3). In the literature, this opportunity was specified for VT and VM. This means, an enhanced understanding is provided by enabling the visualization, manipulation, or rearrangement of objects in VT as well as by the virtual representation of products, processes, or activities in VM (see chapter 2.2.3).

By considering the findings from the literature and the interviews, VR promotes a better understanding of circumstances through visual illustration and a direct user exchange. Nonetheless, there are further parameters necessary to consider, for example language barriers, in order evaluate a quick and profound understanding.

**Seamless transfer of information**

One of the interviewees was concerned about how VR enables a seamless transfer of information due to the many suppliers involved in the product development process (see chapter 4.3). The literature generally underlined the importance of sharing information between all parties involved to ensure a successful PD process (see chapter 2.1.2). With regard to the application of the VR technology, the literature saw this as an opportunity for Virtual Factories by reasons of simulating the whole production facility including individual production processes (see chapter 2.2.3).

Accordingly, product developers see a challenge in the transfer of information when it comes to VR in the PD. This view is motivated by the fashion industry’s characteristics including many actors involved, outsourced departments, and a fragmented supply chain. The literature sees this contrary to the view of the interviewee as it supposed that VFs enhance a seamless transfer of information.

**Product**

*Optimized product design features*

Two interviewees saw the opportunity to depict changes of the product directly which supports the decision making process. In addition, it was stated that the differences between the virtual and real product are minimal, which allows to optimize product design features. One interviewee further mentioned that VR tools give the opportunity to adjust products easily and to see the changes from every angle. With regard to this, it was argued that VR enables to apply the 3D product in the real world. In addition, one interviewee noted an improvement in the communication to the suppliers due to fewer misunderstandings regarding the design features of the product (see chapter 4.3). Relating to this opportunity, the literature emphasized that through VR in VP the product can realistically be simulated and visualized as well as the movement behavior can be illustrated which enables to adjust and enhance the product design. The literature additionally highlighted the benefit that these adjustments can be reviewed in real time (see chapter 2.2.3). Thus, this opportunity can positively influence a
product’s success in terms of the success factor of providing ‘unique and superior products’ that serve as differentiation factor to competitors due to the optimized product design features (see chapter 2.1.1).

The VR technology is regarded as beneficial for the simulation and optimization of product design features by the interviewees and the literature. The chance to adjust a product in real time is an opportunity, making the VR technology a valuable tool in the cost and time driven fashion industry.

**Insufficient fidelity of tactile feedback**

Only two interviewees referred to insufficient fidelity of the tactile feedback. The importance of being able to touch products in the product development process of garments was highlighted. Further, the significance of getting feedback from the fitting model was stressed. However, it was noted that the tactile feedback is not needed for all products. Therefore, VR might be applicable for basic products which are less critical regarding the precision (see chapter 4.3). The literature also stated that the tactile feedback is a major challenge in the implementation of VR in the PD. This issue is linked to the lack of understanding of the human perceptual system as well as the translation of touch signals. However, the literature mentioned that there is some research about the translation of haptic feedback in VR (see chapter 2.2.3).

The literature and the interviewees agreed that the insufficient fidelity of the tactile feedback is an issue, especially regarding the fashion industry. Therefore, improvements and further developments in the Virtual Reality technology and more research about the human perceptual system are needed to overcome this challenge.

**Risk of inaccurate imitation of the product**

With regard to this specific issue, it was stated that creating a VR image which resembled a real product is very challenging. In that regard, it is important to consider that the real product is being purchased, not the virtual one, as mentioned by one interviewee. Another challenge highlighted was to overcome details like lighting (see chapter 4.3). With regard to the risk of an inaccurate imitation of the product, the literature claimed the importance of considering the highly malleable characteristic of clothes which can cause difficulties in the virtual product imitation. The literature additionally emphasized that the product imitation is critical because of limited haptic interaction with the virtual product (see chapter 2.2.3).

Both, the interviews and the literature show that this risk needs some attention. Therefore, it is essential to improve the VR technology with regards to the current inaccuracies. A virtual imitation of the product that is as accurate as possible is needed in order to positively impact the PD.

**Process**

**Improved processes**

As shown in chapter 4.3, all interviewees mentioned the opportunity to improve processes in the PD of fashion items through the implementation of VR. In this context, it was argued that VR enhances the overall processes in a way that it reduces the need for physical samples and cuts down waiting times. Furthermore, it came up that VR speeds up the PD processes since it allows all participating actors to work and communicate in one common tool. Accordingly, time for decision making and production can be significantly reduced which may also have a positive impact on costs. However, one interviewee scrutinized the impact of VR on the
current PD process and highlighted that one should be aware of all the changes which come along with the implementation of the technology. For instance, previous time schedules, meetings, and the distribution of tasks would need some reconsideration and might need to be rearranged. The literature review identified the improvement of processes as a general opportunity of VR in the PD. It stated that the implementation of VR is able to enhance the effectiveness of the overall product development process by improving systematic procedures, decreasing time to market, allowing the interaction with users, operations and objects, and leading to greater cost competitiveness (see chapter 2.2).

By comparing the responses from the interviews with the literature, it becomes obvious that the experts from the fashion industry agreed with the explanation from the theory. For this reason, it can be interpreted that the issue of improved processes presents an important opportunity for the implementation of VR in the PD in the fashion industry. Despite all this, it should be noted that the implementation of VR in the PD needs an overall review of the current procedures and structures as well as considerations about potential rearrangements so that it can lead to the required process improvements.

**Bespoke solutions for the PD process**

In line with this opportunity, one interviewee claimed that the application of VR may be beneficial as it accelerates and simplifies the product development cycle and saves costs since the products can be easily adjusted in the VE. In addition, it enables the product developers to interfere in the development process of the product whenever it is necessary and allows a more visual interaction between designers and developers to share ideas (see chapter 4.3). According to the literature, VR in manufacturing strives for providing bespoke solutions for the entire PD process which makes new ways of development possible, allows to evaluate and simulate complex processes digitally and to assess potential manufacturing decisions prior to the creation of the physical product (see chapter 2.2.3).

The interviewee shared a similar view as the literature with regard to the opportunity to allow bespoke solutions for the PD process, though without explicitly relating it to any specific area of application. Thus, VR as an enabler of tailored solutions to any product development process can be regarded as a useful tool for the PD in the fashion industry. This interpretation is based on the interviewee’s opinion that VR could enable product developers to intervene in the product development process and to adjust the fashion product as often as it is necessary in order to get the best possible solution before going into production.

**Increased flexibility**

Two interviewees perceived VR as a useful application to increase flexibility in the PD process (see chapter 4.3). It was even mentioned that flexibility presents one of the main benefits of VR in the overall PD process in the fashion industry due to its possibility of satisfying customer requirements in real time. In doing so, customers would get exactly the product they want at a desired time instead of waiting for it until the trend is almost over. The literature mentioned the integration of the ‘agile methodology from the software development’ into the PD of physical products as a vital success factor as it allows to react to changing requirements in a flexible and fast manner (see chapter 2.1.1). Regarding the VR technology, the literature related this opportunity of increased flexibility to the area of Virtual Training (see chapter 2.2.3) since the use of VR allows employees to be trained on a consistent but flexible basis, no matter the needs of the training or current position.
The comparison between the interviewees’ answers and the literature shows that the two respondents did not restrict this opportunity to the area of VT. Rather, increased flexibility was seen as an important opportunity to respond to customer needs in a timely manner. Considering today’s volatile fashion industry which is marked by short product life cycles and rapidly changing consumer demand (see chapter 2.1.3), a high level of flexibility is crucial to fulfill customer requirements on time. Hence, from this point of view, increased flexibility represents a striking opportunity. On the other hand, the argumentation from the literature which highlighted the importance to keep employees trained, especially with regard to the continuous development of new technologies, should not be neglected (see chapter 2.2.3). The application of VR in trainings would allow to school employees from any place in the world which represents a considerable advantage for the globally fragmented industry. For all the reasons given above, the opportunity of increased flexibility can be regarded as relevant for the PD in the fashion industry.

Testing and Evaluation
Evaluation of product and production decisions prior to the product realization
The opportunity to evaluate product and production decisions prior to the product realization was not really seen by the interviewees. On the contrary, it was even highlighted that at some point, the evaluation of products still requires a physical sample and a real fitting model. This statement was justified by emphasizing the need to touch and feel the product before it can finally go into production. One interviewee agreed with this statement only in relation to complex and high quality garments like suits, but did not see the importance of physical prototypes for basic products like jerseys, since such fabrics and materials are well known (see chapter 4.3). The aforementioned opportunity was listed in the literature about VP and VM. In terms of VP, the use of VR allows to find product design alternatives and to test and validate performance, aesthetic features, functionality, etc. before the physical product is created. Thus, all relevant product features and its behavior can be visualized, displayed, evaluated, and adjusted in a simulated environment before putting the production into action (see chapter 2.2.3). This is especially beneficial considering that the development of new products in unfamiliar territories bears a high risk of failure as the necessary experience and knowledge is lacking in the specific field (see chapter 2.1.1). With regard to the manufacturing side, VR enables to foresee and prevent potential loopholes in the manufacturability of products before the production process starts (see chapter 2.2.3). Therefore, production decisions can be evaluated and changed before realizing the final product (see chapter 2.2.3).

The juxtaposition of the interviewees’ opinions and the literature indicates that the product developers relate this opportunity more to the application of VR in prototyping than in manufacturing. To them, it seemed more important to validate the product features, like materials and shapes, than the manufacturability of the product before it gets physically realized. On the basis of the results, it can be interpreted that the evaluation of producibility decisions is not really part of the product developers’ responsibility and therefore, they did not consider it during the interviews. Concerning the application of VR for prototyping and fitting, the literature agrees with the interviewees’ opinions that in some cases, physical prototypes are still necessary because a garment’s fit on a body is dependent on physical and mechanical specifications as well as the interaction between the body and the garment (see chapter 2.2.3). For these reasons, it can be concluded that the evaluation of product decisions prior to the actual product realization represents an opportunity of VR in the PD in the fashion industry especially in terms of new products in an unfamiliar field. However, a physical prototype should not be totally replaced.
Employees

Encouraged participation and enthusiasm

The opportunity for VR to encourage participation and enthusiasm was less denoted as such than it was critically illuminated by four interviewees (see chapter 4.3). In that regard, the challenge to convince older product developers of the implementation of VR was mentioned as they often seem quite inflexible and refuse changes towards new systems or tools. On the other hand, it was stated that younger generations are more likely to be encouraged for changes as they are typically more flexible and are willing to adapt to new applications. Moreover, the importance of the top management commitment to encourage the employees for the change was highlighted and the need to nurture them with sufficient information regarding the implementation process of VR in the PD. The literature review also stressed the ‘top management support’ as an important success factor of the product development and thus agrees with the opinions of the interviewees (see chapter 2.1.1). One product developer took a cultural perspective on this issue and stated that the cultural change represents a much bigger challenge than the technology change itself. This statement is confirmed by the literature stating that climate, leadership, and culture are often difficult to influence (see chapter 2.1.1). The interviewee continued that VR would not present an encouraging tool for every fashion company, because the application would mean to abandon a handicraft. The literature associated this opportunity with the area of VT, noting that the application of VR in trainings can be beneficial as it provides the participants with an encouraging and exciting experience compared to conventional trainings (see chapter 2.2.3).

The summary of the results from the interviewees’ answers demonstrates that the product developers took a far more critical stand than the literature regarding the above mentioned opportunity. In light of the statements from the interviewees, the application of VR does not necessarily lead to encouraged participation and enthusiasm. Rather, it is highly likely that the implementation of the VR technology would be rejected by some employees because they do not see the benefit of it but the effort they have to make. In addition, the top management should be able to encourage its employees for the change which would mean that the top executives had to be open for and convinced of the new technology. In consideration of all those aspects, the opportunity is not regarded as persuasive enough to consider the implementation of VR in the PD in the fashion industry.

Impacts of mistakes are alleviated

The interviewees did not explicitly mention the opportunity of VR to alleviate mistakes due to its ability to enable the users to work on a virtual object instead of on a real one. Instead, one interviewee pointed out the importance to authorize mistakes in the starting phase of the introduction of VR in the PD even though every mistake would cost money (see chapter 4.3). Regarding the literature review, the advantage to alleviate impacts of mistakes occurred in the area of VT in the sense that VR in trainings prevents participants to make mistakes on the real product and to this effect inhibits discouragement, infliction of harm to the environment, damage to property or equipment, and costs (see chapter 2.2.3).

The interviewee’s answer and the literature show two opposing perspectives on VR and its relation to mistakes and both are justified. On the one hand, the implementation of VR in the PD will not proceed without any mistakes. For this reason, it is important to encourage the product developers to try the new technology and to allow mistakes. On the other hand, it is expected that the users would be pleased with the opportunity to train specific capabilities on a virtual product before they have to work on the real one. Especially by considering the overall PD process with all its stages and quality control checkpoints (see chapter 2.1.2), it
can be assumed that a virtually simulated process would be beneficial to detect and eliminate mistakes in favor of time and cost expenditures.

**Lack of technical knowledge of users**
The last risk of the theme ‘employees’ referred to the lack of technical knowledge of users (see chapter 4.3). All five interviewees expressed the importance to obtain knowledge about the new technology and how to use it. In this connection, it was mentioned that currently product developers do not have sufficient experience with VR systems. Therefore, it would be important for the product developers to acquire new soft and hard skills in order to be able to handle the VR technology. The literature described this issue as one of the main challenges of Virtual Prototyping (see chapter 2.2.3). Accordingly, the learning process for the VR technology is quite time consuming and requires a great deal of effort.

The comparison between the interview responses and the theory reveals that the five product developers agreed with the literature about the issue of the lacking technical knowledge of users. Even though four out of the five interviewees intimated that their companies have considered or even pretested VR in the PD process, there was still a persisting ignorance among the employees. Further, it should be mentioned that the interviewees’ attitude towards the learning of the VR technology seemed quite critical as they expressed their concerns about some product developers who might not see the point of the technological change and therefore, would reject to make the required learning effort. For those reasons, the lack of technical knowledge of users can be considered as a major challenge of the implementation of VR in the PD in the fashion industry.

**Customer**

*Integration of VOC in the PD*
The opportunity of integrating the VOC for customized options was named by two interviewees. The application of VR was perceived as beneficial for the PD process in the fashion industry in a way that it would allow the customers to be involved in the decision making about the product from the beginning. Further, the customer would be able to see the garment from a first person perspective, change colors according to his or her preferences, and provide the product developers with feedback. This could lead to more satisfied customers who get exactly the products they need at the time they need them and consequently to increased sales (see chapter 4.3). In the literature review, this opportunity was assigned to the area of Virtual Prototyping (see chapter 2.2.3). Additionally, the full satisfaction of customer requirements and the integration of the Voice of the Customer into product decisions was mentioned as a critical success factor at the project level. Therefore, this is nowadays vital to gain a competitive advantage (see chapter 2.1.1). The use of VR may allow customers to approve the design and pre-evaluate the product’s ergonomic features as well as its usability before it will be physically realized.

Thus, two of the product developers saw the VR-related opportunity of integrating the VOC for customized options also for the fashion industry. Nonetheless, it can be interpreted that this opportunity is only noteworthy if fashion companies provided the customers with access to the VR software and hardware.

*Tailored design to exact body shapes*
One interviewee noted this opportunity by pointing out that the use of VR would provide the customers with a wider range of styles and fits (see chapter 4.3). The literature review about
VP highlighted that VR allows garments to be designed according to the exact body measurements of customers without their actual physical presence (see chapter 2.2.3).

By comparing the opinion of the interviewee with the literature, it becomes evident that both saw the possibility of tailored designs according to individual fits as a striking argument for the implementation of VR. The fact that the customers do not need to be physically present but can virtually try on the products from their homes makes this point even more valuable. However, this would presuppose that the customers have the necessary VR devices at home.

*Lack of technical knowledge of users*

The lack of technical knowledge of users with regard to the customer was named by two interviewees (see chapter 4.3) who scrutinized whether the VR technology would represent a too big hurdle for the customer. As mentioned in the prior theme ‘employee’, the issue of lacking technical knowledge of users was depicted as one of the biggest challenges of Virtual Prototyping (see chapter 2.2.3).

The views of the interviewees as well as the literature on the topic indicate that the VR technology has not been widely tested by users so far. The interviews showed that all five product developers had very limited experience with VR both in their private and professional life and that this technology seemed currently quite abstract and futuristic to them (see chapter 4.1). Hence, it can be interpreted that the use of VR in the private life of consumers has not gained much attention yet. Therefore, the customer use of VR for product development purposes seems to be quite far from today’s PD operations.

*Software*

*Insufficient software capabilities*

As illustrated in chapter 4.3, the issue of insufficient software capabilities was considered by several interviewees. One of them criticized the VR software for its inability to mirror the right optical features of the product. Another interviewee expressed some doubts regarding the lacking software capability to convey the haptic properties. Moreover, concerns about potential errors in the software were expressed and that especially small companies are not able to implement VR because of their incapable systems and software tools. One interviewee further considered the fast development of the VR software and that a company might struggle in keeping up with that pace. The literature referred this problem to the area of VF and highlighted that the need for virtual data management, automated systems, flexible and consistent simulation, and communication and integration in order to create a Virtual Factory, imply a significant challenge to most software systems (see chapter 2.2.3).

Whereas the literature related the problem of insufficient software capabilities to the creation of a Virtual Factory, the interviewees were more concerned about the inaccurate projection of the optic and haptic product features, the risk of not keeping pace with software developments of VR, and potential errors in the software. The interviewees’ answers show that the implementation of VR in the PD in fashion is still associated with a lot of uncertainty and that the product developers are skeptical about the current status of the VR software. With regard to fashion products, which are highly dependent on their aesthetic and tactile features (see chapter 2.2.3), the VR software should be capable to represent the products realistically and prevent any errors which could falsify them. However, the interviewees doubted that the software would be able to reproduce them in a realistic simulation. Therefore, the above mentioned problem is assessed as critical and needs consideration in context with the introduction of VR in the PD in the fashion industry.
Incompatibility of systems

The incompatibility of systems was mentioned by two interviewees in the sense that there is a big gap of technological levels between retailers and suppliers. In that regard, it was stressed that it would be difficult to introduce VR in the PD if the suppliers did not work with this technology. On the other hand, VR was seen as beneficial since it could connect all supply chain partners (see chapter 4.3). According to the literature, one of the main disadvantages in Virtual Manufacturing is the import and export of data between different systems which can be traced back to a lack of available data and the incompatibility of systems (see chapter 2.2.3).

The concerns of the interviewees show that the issue of incompatible systems does not only represent a challenge for the application of VM in general, but also for the fashion industry as a whole. Considering the globally distributed fashion supply chain (see chapter 2.1.3) and the interface function of the product developers between suppliers, manufacturers, and designers (see chapter 4.2), it becomes obvious that a VR system in the PD can only be regarded as advantageous when it can be used by all the interacting parties and when their systems are compatible. However, as demonstrated in the results, it is unlikely that suppliers from Asia for example, would implement VR into their operations and adjust their systems accordingly. Thus, the issue of incompatible systems can be perceived as a key challenge in implementing VR in the PD in the fashion industry.

Hardware

Uncomfortable devices

The aspect of uncomfortable devices was given attention to by two interviewees. One criticized the overall hardware which needs to be worn and set up for the use of VR which seemed too effortful to the interviewee. The other regarded the VR glasses as a quite inconvenient application and claimed that they would be impractical to wear during sales or concept meetings (see chapter 4.3). The literature review drew attention to this problem in the area of Virtual Prototyping, saying that the user must wear this uncomfortable equipment in order to be able to immerse in the virtual world (see chapter 2.2.3).

The answers from the interviews demonstrate that the hardware, which is an inevitable component of the VR technology, was perceived as inconvenient and discomforting by the product developers. Especially the VR glasses were regarded as bothering and unsuitable for meetings. This point can be examined from two sides. On the one hand, the use of the VR hardware in meetings could of course be disturbing and would not make much sense when all participants were gathered at the same place. On the other hand, given that participants from distributed areas might need to attend the meeting, the use of the hardware could be beneficial as it would prevent the necessity for all parties to travel to the respective meeting place (see chapter 2.2.3) and allow them to get all necessary information via the virtual system (see chapter 2.2.3; chapter 4). Therefore, the disadvantage of the uncomfortable devices should be weighed against the opportunities which the use of VR would entail for the fashion company.

The previous paragraphs only discussed the results that were mentioned both by the interviewees and in the literature. However, the literature identified further opportunities and challenges which have not been brought up in the interviews. These are presented in Table 9 relating to the assigned theme.
Table 9: Remaining opportunities and challenges from the literature
Source: own illustration

<table>
<thead>
<tr>
<th>Category</th>
<th>Opportunities and Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>early fault detection, increased operation efficiencies, impacts of mistakes are alleviated,</td>
</tr>
<tr>
<td></td>
<td>mistakes in measurements</td>
</tr>
<tr>
<td>Time</td>
<td>early fault detection, concurrence of activities, decreased number of prototypes produced</td>
</tr>
<tr>
<td>Environmental</td>
<td>early fault detection</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>improved documentation of the PD process</td>
</tr>
<tr>
<td>Product</td>
<td>early fault detection</td>
</tr>
<tr>
<td>Process</td>
<td>enhanced assembly and production line capacities, improved documentation of the PD process,</td>
</tr>
<tr>
<td></td>
<td>optimized floor layout</td>
</tr>
<tr>
<td>Evaluation &amp; Testing</td>
<td>enhanced evaluation and control of systems</td>
</tr>
<tr>
<td>Employees</td>
<td>constant training for skilled employees, risk of sickness, risk of emotional or physical</td>
</tr>
<tr>
<td></td>
<td>damage, risk of confusion between virtual and real environment</td>
</tr>
<tr>
<td>Customer</td>
<td>risk of confusion between virtual and real environment, risk of sickness</td>
</tr>
<tr>
<td>Software</td>
<td>lack of data</td>
</tr>
</tbody>
</table>

It is interpreted that these opportunities and risks were not mentioned by any of the interviewees because of their lacking knowledge about and experience with the use of VR. For this reason, they cannot be discussed or compared with the literature. Nevertheless, the literature emphasized their importance with regard to the PD in manufacturing industries (see chapter 2.2.3). Therefore, they should not be neglected even though no assumptions can be made for the product development in the fashion industry.

The literature depicted a lot of opportunities for VR in the product development (see chapter 2.2.4) and many of them were also discussed by the interviewees. On the other hand, both saw Virtual Reality in the product development as difficult due to several challenges which could impede its implementation and application. However, all interviewees believed that Virtual Reality will play an important role in the future product development in the fashion industry, at least in some areas like Virtual Prototyping (see chapter 4.3).
6 Conclusion

The last chapter aims to provide a short summary of the thesis’ purpose and to answer the research questions. In addition, theoretical and practical implications are pointed out, research limitations are described as well as recommendations for further research are given.

6.1 Answer to the Research Questions

This thesis aimed at examining how VR can be applied in the PD in the fashion industry. Current developments in the VR technology and its success in other industries raised questions regarding the application of the technology in the PD in the fashion industry. Moreover, there is a lack of coverage in the literature for this specific research subject. Therefore, the following research questions came up:

RQ 1: Which areas of application of Virtual Reality in the product development are perceived as relevant for the fashion industry by product developers?

RQ 2: What are the opportunities and challenges in implementing Virtual Reality in the product development process for the fashion industry?

In this regard, the literature review provided an overview of the product development in general and in the fashion industry and guidance to the topic of Virtual Reality. The literature pointed out that VR in the product development can be applied to four distinct areas in manufacturing industries, including Virtual Training, Virtual Prototyping, Virtual Manufacturing, and Virtual Factory. In line with these four areas of application, several opportunities and challenges were elaborated. The empirical data reflected the perspectives of five product developers concerning the relevance of the four areas and the opportunities and challenges of VR in the PD for the fashion industry. On this basis, the research questions are answered as follows.

RQ 1: The literature identified four areas for the application of VR in the PD of manufacturing industries: Virtual Training, Virtual Prototyping, Virtual Manufacturing, and Virtual Factory. The importance of the four areas for the fashion industry was perceived differently by the product developers. Virtual Prototyping was regarded as most relevant as it would provide the most opportunities to a fashion company compared to the others, for instance, the decreased need for physical prototypes resulting in time and cost reductions. However, the interviewees also acknowledged VT as a potential application area for the PD in the fashion industry, especially if globally distributed employees need to participate. Nevertheless, they stressed the importance to clarify the necessity for VTs. VM and VF were seen as important for the fashion industry but were not part of the interviewed product developers’ area of responsibility. In this regard, the interviewees further highlighted that the capabilities and commitment of the suppliers are decisive in integrating VR in their processes.

RQ 2: Several opportunities and challenges were mentioned, both by the literature and by the interviewees (see chapter 5.3). Throughout the interviews the opportunities relating to the themes ‘time’, ‘cost’, ‘process’, and ‘communication’ were particularly highlighted. With respect to time, the implementation of the VR technology was seen as an enabler to shorten the whole product development cycle and to react to the customer demand more quickly. The interviewees further mentioned that the product development costs are likely to decrease in the long term as the use of VR would come along with the need for less physical prototypes
for example. For the theme ‘process’, the interviewees emphasized an overall improved PD process, especially in terms of efficiency. Lastly, the product developers mentioned that VR would allow an enhanced communication between globally distributed parties. In contrast to this, the themes ‘cost’, ‘employees’, and ‘software’ were claimed as main challenges. Accordingly, the interviewees spoke of the high development and implementation costs. From an employee’s perspective, the product developers mainly brought up the lack of experience with VR. Incompatible systems of supply chain actors as well as insufficient software capabilities were also named as challenging factors.

The interviews indicated that VR is of topicality in the PD in the fashion industry. However, it became evident that the interviewees illuminated the topic from two different perspectives. On the one hand, they saw important opportunities in the implementation of VR in the PD. On the other hand, all interviewees expressed their concerns regarding the feasibility of the implementation of VR, which can be referred to the novelty of this subject and the inexperience with its use.

6.2 Theoretical and Practical Implications

The scientific community benefits from the research as it contributes to fill the research gap regarding the implementation of VR in the PD in the fashion industry. Hereby, the work considers relating areas of application as well as opportunities and challenges. Thus, this thesis adds value to the existing body of literature and important insights. Since the study represents a starting point for further research, the scientific community can use it to get an overall understanding of the topic and to generate further research ideas.

The thesis is relevant for the fashion industry because it stresses several aspects that need attention in the implementation of VR in the PD. Fashion companies get an idea where this technology can be applied and what to expect and consider when introducing it. Thus, they can prepare themselves for possible challenges and include them in their project and time management. This thesis provides stakeholders with an understanding of the whole topic and demonstrates potential obstacles but also the long term benefits. Therefore, it can help in making decisions regarding the implementation of VR in the PD.

6.3 Limitations

The literature review was mainly limited by a research gap in the area of Virtual Reality in the product development in the fashion industry. Therefore, it referred to VR in the product development of manufacturing industries in general. Due to the limited time and scope of the thesis, data from only five interviews were gathered and interpreted for which reason the results cannot be generalized. However, the interview results were supported by a thorough literature review which enabled to get a profound insight into the topic and emphasized its relevance for fashion companies. Further, the thesis solely projected the product developers’ perceptions and opinions about VR in the PD in the fashion industry and therefore, the results cannot be taken as universally valid. Nevertheless, since the authors of this study discussed the results in comparison to the literature and since it is supposed to depict the current status in the industry, the research keeps its value. In addition, the thesis was further limited by the fact that only data from interviewees working in global fashion companies were gathered. Hence, the perspectives of local working fashion companies were neglected. In this context, only product developers were interviewed, but not other departments that play a vital role in the product development process, such as Marketing or Production. Moreover, the young age
of the interviewed product developers and their restricted work experience in the PD in the fashion industry gave a scarce view on the topic. However, the significance of the research was maintained as it provided a profound base for further research on this unexplored subject.

6.4 Further Research Recommendations
The representativeness of this thesis could be enhanced by using a bigger sample or interviewing product developers with more work experience in the product development in the fashion industry. In addition, it would be interesting to get insights from more diverse perspectives, meaning to interview not only product developers but also business developers, Top Management, or the financial department for example. Another research implication would be to cover the four defined areas of application more thoroughly by focusing on them individually. Further research could also look at the supplier and manufacturer side since capturing their viewpoints and considering their capabilities might lead to interesting implications for the whole supply chain.
References


Appendix

I Affidavit

We hereby certify that this paper is our own work and that we did document all used sources and materials. Furthermore, all verbatim extracts and references have been quoted and all sources of information have been acknowledged. This paper was not previously presented to another examination board and has not been published yet.

Borås, June 11, 2019  M. Döring
Place and Date     Signature

Borås, June 11, 2019  M. Flosdorff
Place and Date     Signature

Borås, June 11, 2019  T. da Silva
Place and Date     Signature
II Interview Guide

General questions
1. What is your name?
2. How old are you?
3. How long have you been working in the product development?
4. At which company are you working?
5. What position do you have in the company?
6. How do you define product development? What are you doing?
7. Which tools are you currently using in product development?
8. What do you think is the future of product development in fashion?

Virtual Reality
1. Have you ever used VR?
2. What do you think about VR? How do you feel about VR?
3. How do you define VR?
4. Our definition of VR: VR is a widespread technology providing users with an experience of interaction and immersion, and creating virtual environments which conquer the spatial and physical boundaries of the reality. It allows an individual to make ‘artificial’ experiences in a virtual world which are created by computers and which are perceived as real by the user since this world allows him or her to see, hear, or grasp things just like in the reality.
5. Is your company currently using VR in the product development process?
   a. If yes, in which part of the product development process?
   b. If yes, why was it implemented?
   c. If yes, how did they implement it/ prepare the users?
   d. If yes, what is the difference to the previous system?
6. Is your company aiming to implement (more) VR?
   a. If yes, in which department?
   b. If yes, how are they preparing you?
   c. If no, do you know why?
7. In which ways do you think it might be useful to apply VR in product development in fashion?
8. According to the literature, VR in product development is mainly applied in the areas of training, prototyping, manufacturing and factory (short explanation of the 4 applications).
9. How do you understand these four areas?
10. Our Definitions:
    VM: VM comprises the simulation of products and related manufacturing processes
    VP: Virtual prototypes are used by designers, engineers or end users to test and assess an intended product’s aesthetic features, its functionality, ergonomics, and usefulness in a VE.
    VT: By the use of forefront VR technology, training is held in a simulated environment, which seems realistic to the actual training facility.
    VF: VF refers to how VR can be applied to the production facility design. It serves as a virtual representation of the actual factory, along with, but not limited to, its construction, machinery and supporting equipment and simulates production in a virtual factory environment.
11. What areas do you think are relevant for product development in fashion?
    a. Why?
12. Do you think there is the need to have different skills as fashion product developer in using VR?
   a. If yes, which skills are most relevant?
   b. If no, why not?
13. What are the challenges you see in implementing VR in product development in fashion?
   a. For the company
   b. For you
14. What are the opportunities you see in implementing VR in product development in fashion?
   a. For the company
   b. For you
15. What do you think is the future of product development in fashion?

III Interview Information

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Date</th>
<th>Duration</th>
<th>Place</th>
</tr>
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<td>May 4, 2019</td>
<td>22:15 min</td>
<td>Borås, Facetime</td>
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<tr>
<td>B</td>
<td>May 4, 2019</td>
<td>52:15 min</td>
<td>Borås, Facetime</td>
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<td>C</td>
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<td>D</td>
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<td>E</td>
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