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DIGITAL TRANSOFRMATION OF APPAREL INDUSTRY: 3D PLATFORM

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Abstract

The aim of the work is to provide some insight for the improvement of product lifecycle and decrease the environmental footprint in the apparel industry with the introduction of software 3D, making the case of the company Pattern SpA. To do so, it is analysed the actual product life-cycle, focalizing on the information system of the company and explaining, under some assumptions, how an ideal platform that exploits the 3D technology could be used in order to reduce the life-cycle time, the costs and the material consumption. It founds obvious limits for the development of this platform, thanks to the technological limits that the apparel industry shows. However, it is thought a structure that could improve the actual product life cycle, making a first step for the utilisation of 3D in the apparel sector.

Summary

Introduction

Nowadays the apparel industry is not more a closed and independent world, but it has allowed itself to be influenced by several dimensions. It involves different sectors, from marketing and psychology, to economy and technology. The relationship between the technology and fashion is tight, thanks to the fact that the technology is sensitive to the market problems. Furthermore, the industrialization has allowed to innovation in the production taking into consideration the costs and the environment.

The fast fashion allowed the companies to accelerate the time-to-market and consequently also the time to customer will be reduced. The problem is due to the product life-cycle of the apparel industry. The process starts with the conception of the design, with problems of visualization of the clothing, allowing to the production of a sample and that's required time, costs and material. There is the necessity of improvement technologies that permit to increase the productivity level, reduce cost and material consumption, allowing also to a less waste and lower environmental impact.

In the following work an ideal full 3D platform is thought, an instrument that could be to improve the actual product life cycle, allowing to a reduction of cost, material consumption and environmental footprint. It is possible to use it from the design stage until the production. That type of technology is not yet available because of the apparel sector has not reached the same maturity level of the other industries where the use of the 3D in their product life cycle is consolidated.

A first step in direction of the full 3D platform could be the introduction of several elements that permit to have a clear visualization of what the clothing will be, taking into consideration the drape and the type of textile, and to have an efficient level of productivity.

The work is structured as follows:

Chapter 2 is a study of the apparel industry and the necessity of technology improvement using the industry 4.0 philosophy: the fashion 4.0.

Chapter 3 is an analysis of which type of software are used in the Pattern SpA company, explaining which type of work that they support.

Chapter 4 explains the possible features of a hypothetical platform that uses the 3D during all the steps of the product life cycle, an analysis of cost and material consumption is done. Consideration and limits of that type of technology are analysed.

Chapter 5 provides an alternative that allows the introduction of the 3D in the product lifecycle, due to the fact that there is not a technology able to support all the stages of the garment creation.

1. Summary of actual state

1.1 The apparel industry: the evolution

The apparel industry is one of the first sector to appear. In the past, the article of clothing was used because of the necessity to cover the body, then assumed a social role, to identify the different social classes because of different quality of fabrics, the design and the richness of material. Nowadays, fashion is a way to distinguish themselves and to affirm social or political messages [1].

At the beginning of the apparel industry, the mechanized process did not exist, and the cloths were made by seamstress or were home production, so the process, was made by only one person and to sew an article of clothing required a lot of time. This type of articles was made only for one person or a small group, so each article was one-of-a-kind. After the second post-war period the mass production started, and the cloth production was standardized, the time required to produce one piece was reduced and the cost production decreased using cheap material with lower quality. All these changes were made to meet the need of the mass [2].

Nowadays with the birth of the Fast Fashion, term used to express the design that want to capture current fashion trends. It is based on the trends based of the Fashion Week of both the collection, Autumn/Winter and Spring/Summer. These trends are designed and manufactured quickly to meet the need of the customers, who want high variety at lower cost. The companies to satisfy this need, have to give up the cloth quality, the eco-friendly process and the work ethic. There are some companies, that belong to the luxury segment, had to make some variations about their methodology to sell their product because of changes of the market. They started with the concept *See-Now-Buy-Now.* With this method, the brand gives the possibility to buy after the collection show, the cloth and the accessories already showed. The costumer could buy the objects using the e-commerce, in the boutique or in selected flagship store. One of this brands that use this methodology are *Burberry*, *Tommy Hilfiger, Tom Ford* and *Moschino.* The idea is to be near to the customer and satisfy their enthusiasm and need to be the first to buy one of the pieces of the collection after the show [3] [4] [5].

1.1.1 Collection development

The apparel industry is characterized by rapid changes because the market is characterized by short lifecycle, high volatility, high impulse purchasing and low predictability. In the fashion industry, to ideate a new collection, the process done is the New Product Development (NPD), which depends by high seasonal demand and by the nature of fashion products. The process is taking part two times or more per year and requires revisions because of changes decided by the stylist and other actor who take part to the NPD. The **NPD** [6] [7]is the result of interaction between different subjects (stylist, communication manager, production manager and brand manager). The NPD process follows seasonal events and it presents different phases. The different collections are developed following main fashion fair. The autumn/winter collection would be delivered to retailers between June and August, and it is presented at the fashion fair between the end of January and February. The spring/summer collection would be delivered to retailers between January and February, and it is sold since the end of February and at the beginning of March. The collection is showed at the fashion fair occurred between July and September of the previous year. The development of the collection starts five months before of the show at the fashion fair [8]. The NPD can be divided in:

1. Market Analysis
2. Collection development
3. Industrialization
4. Production and Distribution

1.1.1.1 Market Analysis

First of all, it's important to **define the market segment** where the collection could be positioned. The product positioning is defined by the market segment where the collection is positioned, and it requires a periodic check to understand if the position of the collection is correct with respect to the competitors and the market response. When the position of the is defined, it will be analysed the trends of the market.

The **trend analysis** is like a *black box* because it's difficult to describe the way in which the trends born. In this case the designer, consultant, cool-hunter take part of this phase. The designers have large autonomy because they not have to take in consideration the production and logistic area, they are the artist, and take part to the creative phase. The information flow goes from the designer to production and logistic area. The analysis starts at the beginning

of the collection development for the new season, so five or six months before the presentation of it. At the end of the trend analysis there is the presentation of the *mood or concept board*, a billboard where there are summarized the themes of the new collection.

1.1.1.2 Collection development

The **collection development** starts after the analysis of the information collect about the trends. The marketing section starts with analysing the results of previous season. This phase commences at the end of sales campaign of the collection of the previous year. At the beginning of this phase is known:

- Information about the success or unsuccess of the sell-in about the collection and for each cloth;
- First information about the starting season of the sell-out cloth.

Thanks to the Pareto analysis, that has the objective to underline the contribution of different models or cloths of the total sales volume, the elements are ordered from the worst selling to the best-selling. The result is a dossier with the models of the previous year to replicate with some adjustment, considering the trend analysis, the models where they will do fundamental changes and models to be eliminated. Subsequently the new models' characteristics and the prices are defined. In this phase the designer is essential, because he gives the originality to the collection. This phase is done four or five months before the collection presentation.

1.1.1.3 Industrialization

Then, in the **industrialization phase**, after the definition of the textiles and accessorizes, and after the technical draws, there is the conversion of the idea in physical product. This phase usually, is not made by the parent company, but is responsible supplier. It's a preparation phase, where the different sketches are analysed to understand if the cloth it's possible to produce. First of all, the 3D sketches send by the stylist are convert into 2D draw of the single components that make the cloth. Thanks to the communication between the pattern makers and the designers, adjustments and minor changes are done in the choice of accessorizes and textiles. The model maker starts the realization of pattern, with a particular textile or the definitely textile. During the realization of the pattern, the pattern maker, will do the adjustment considering the experience. After the realization of the pattern will be sewed the prototype, that is in sample size. The prototype will be submitted to some

correction to be in line with the request of the client. At the end, the result is the definitive prototype, or the sample cloth that will be showed to the customers.

1.1.1.4 Production and Distribution

Given the information of the sample and all the versions, the information about how much textile is used to produce one cloth and the consumption of accessories, and taking into account how many products are sold, the definitive consumption is made. In this phase are also decided which laboratories will deal with the production.

The sales campaign starts with the collection shows, that are a sort of catalogue. After the fashion shows the orders are placed with the method *see now buy now,* but in the past the customers will buy one of the elements of the collection when they are in the stores. The peak is when there is the maximum value of the profit for the company and then a new collection will be developed.

1.2 Industry 4.0

The term 'Industry 4.0' was first introduced in Germany at the Hanover fair in 2011, called also 'Fourth Industrial revolution' [9]. It allows to the transformation of the process in the entire value chain (Fig. 1). The goal of the Industry 4.0 paradigm is the revolution of the traditional industrial production with the integration and the interactivity of all production processes. The digitalization and the automatization of the production and the distribution processes are the principles of this method.

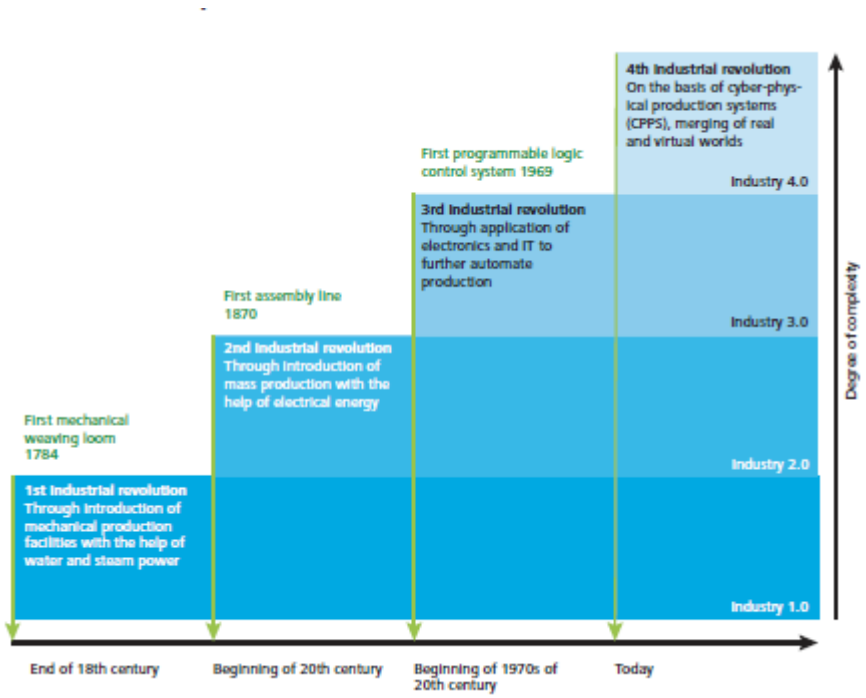


Figure 1 – *Development of the industrial revolution (Source: Deloitte, Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies)*

The diffusion of information and communication technology, in the traditional manufacturing industry, is reducing the boundaries between the real and the virtual word. This is called cyber-physical production systems (CPPSs). The CPPSs link each machine with the other, creating a smart network of machines, properties, ICT systems, smart products and individuals in the whole value chain and the product lifecycle.

It's fundamental for the industry 4.0 the interface with other smart infrastructures. The networks and interfaces gave by the industry 4.0 allows to enormous changes in manufacturing in future [10].

1.2.1 Main characteristics of the Fourth Industrial Revolution

The Industry 4.0 is characterized by four main features (Fig 2):

1. Vertical Networking;
2. Horizontal Integration;
3. Through-engineering;
4. Impact of Exponential technologies.

Figure 2 – *The four characteristics of industry 4.0(Source: Deloitte, Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies)*

1.2.1.1 Vertical Networking of smart production systems

The vertical networking is based on the CPPSs to have a rapid reaction of the plants for variation of the demand or stock level. A customized and individualised production for the different type of client is the result of the smart factories, but it's necessary that the data must be well integrated.

Maintenance management and autonomous organisation of production are possible with the CPPSs, so it's possible to link resources and products, and the raw material could be relocated wherever is necessary. The processes are monitored, so the incongruities and the machinery breakdowns are detected automatically. Also, the fluctuation of the market and

the result is a reduction of waste and consequently an efficient use of resources, human, material and energy [10].

1.2.1.2 Horizontal Integration via a new generation of global value chain networks

The new generation of value chain allows to an optimized network that enable an integrated transparency and high level of flexibility and, therefore, increase the optimization.

The CPPSs not only network machines one with each other, but also create a smart network of machines, properties, smart product and individuals across the entire value chain and the entire product life-cycle. The network created by the CPPSs, it's possible to know the product memory, from the inbound logistic to outbound logistics. In this way, the history of any component is registered and can be consulted at any time. The level of transparency and flexibility would increase across the value chain, and the customization for the client is not limited only for the process, but also for all the step of the product lifecycle. The KPI of the product, quality, risk, time and price, are monitored in each sector of the value chain.

This methodology could generate a new business model and become a change opportunity for all the actors involved [10].

1.2.1.3 Through-engineering across the entire value chain

This characteristic of Industry 4.0 occurs during the design, development and manufacture of new product and services. The link between the business and social networks plays an important role in the digital transformation to industry 4.0, so the manufacturing will be subject to enormous changes in future. A new product required to project or to modify a production system. New collaborations are created among product development and production systems because of the integration of the development and production of new products within the product lifecycle.

A feature of the third characteristic is that the data and information are available at all stages of the product lifecycle and this allow to a more flexible process [10].

1.2.1.4 Acceleration through exponential technologies

Exponentially growing technologies are fundamental for the transformation of the actual industry into industry 4.0. Some researches had shown that the Moore's law could be applied to other technological developments different to the computers (Fig 3). The use of exponential technologies implies individualised solutions, flexibility, and cost saving in

industrial processes. Technologies like advanced robots and sensors, developed with the artificial intelligence (AI), allow to increase autonomy and so permit individualisation and flexibilization. The AI could simplify the supply chain stages, planning the driverless vehicle routes and transforming the warehouses more flexibly, increasing the reliability in production or the analysis of big data, but also optimizing the design solution that permits the interaction between humans and machines.

Functional nanomaterials and nanosensors could be used in production control functions to make quality management more efficient and allow to safer interaction for next generation of robots that work with humans.

An example of exponential technology is 3D printing, that allows new product or new supply chain solutions or a combination of the two allowing to a new business model. Important is the scan of quality assurance or the changes that could be applied in the supply chain management and the warehousing. Fundamental is taking into account intellectual property, product liability, custom duty and value-added tax.

With 3D printing must be taken in consideration the material used, because not all materials respect the requirements of the 3D printing for the level of porosity or other characteristics [10].

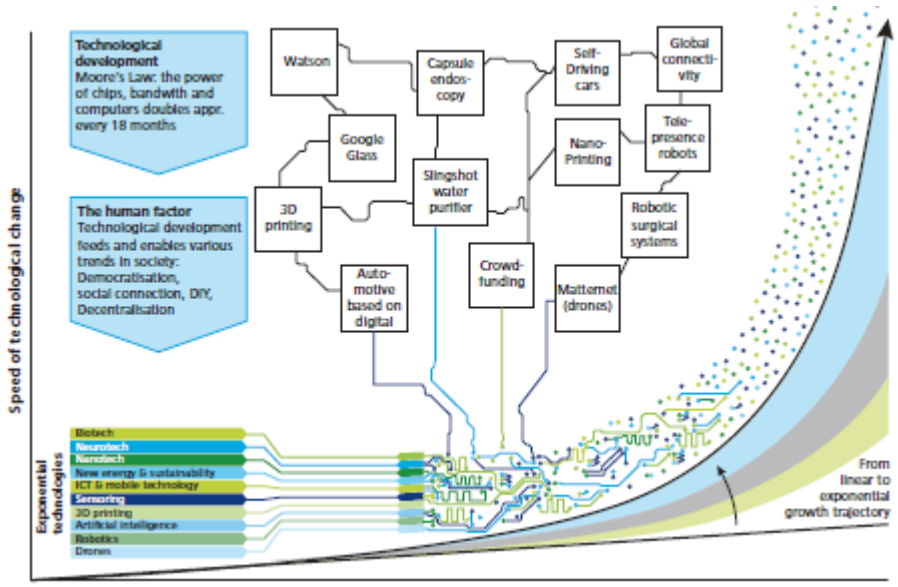


Figure 3 – *Exponential technologies (Source: Deloitte, Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies)*

1.3 Fashion 4.0

The “Fourth Industrial Revolution”, as described previously, is a model where new modes of production and consumption are transformed. Starting from this, it’s possible identify the impact of the industry 4.0 on the textile and apparel industry.

Within the first industrial revolution, there was the first meccanization of manufacturing through water and steam powered technologies, so textile industry was a major appliance of the European and North American industrialization. During the second industrial revolution there was the introduction of electrically powered mass-production based on the division of labour and the apparel industry was again one of the principal actors of this revolution, implementing the mass market production model. Increasing the level of automatization and innovation the industries were transformed all processes. In the third revolution, the industries start to use electronics and IT to achieve further automation of manufacturing. In the apparel industry, the CAD_CAM systems allowed data exchange with a standard software language and brought to the globalization of the fashion industry.

The fourth industrial revolution introduces the potential of internet into a ‘smart factory’, that converge the physical and digital environments. The carried by internet for the connection between machines and humans in the factories has further implications if it’s applied linking resources across their boundaries.

The fashion framework is interesting to be analysed with respect to the industry 4.0 paradigm for different reasons. First of all, the fashion context was a protagonist of the different industry revolutions and nowadays, fashion firms have been at the centre of mass-production dynamics, with the introduction of fast-fashion, transforming and reacting to impacts that technological innovation combined with globalization processes have produced. The fashion sector is a global business and so, the passage to ‘smart factory’ model impacts the efficiency and the sustainability of the production modes.

Secondly, fashion industry is driven by the design and the model traditionally is composed by the designer and the manager; they could create their brand sourcing and their manufacturing system. The impacts of 4.0 paradigm is high, taking into consideration the available technologies.

Least, the fashion industry, so the textile and the apparel industry, is market-driven and with respect to the philosophy of the fast-fashion, based on the ready-to-wear model, this means

that the fashion is touched by innovation which transform interaction between companies and customers.

When fashion and tech merge, the result is a ‘smart product’. This scenario brings the potential value of the 4.0 technologies when used to analyse the data exchanged among smart product, the user community and the company. This allow to a better-balanced market demand, nearer to customer’s needs, so highly customized [11] [12].

1.3.1 Smart factory

Several conditions are to consider for the transition to the industry 4.0. First an attention of Millennials and the interaction and engagement with brands through different devices for an active dialogue. Customers are increasingly interested in attributes of goods and services and all what is around.

Secondly, the real-time exchange of information is not taken in consideration by the traditional model of the ready-to-wear and luxury industry, but thanks to ICT and real time information exchange, the fast fashion re-engineered the traditional cycles. Its cycle is based on vertically integrated value chain, where real-time data drive the quick response approach and the semi-planned production.

Considering the “4.0 smart factory”, there are some technologies which could change the manufacturing processes in the fashion industry: from the laser cutting and linear digital printing to additive manufacturing. This last has a major potential in the production processes for three-dimensional accessories.

Fashion industry seems open to incorporate new technologies in its manufacturing processes, but it not considers two components which permit the transition to the ‘smart factory’. First one is the move into *interoperability* and *virtualization*, common principle to implement the 4.0 industry model. At this moment, companies are not able to implement the continuous exchange of information between object, machines and people through the Internet of Things and the Internet of People, but they try to do it to have the real time control of the processes and also the ability to take action if the system finds criticalities.

The second one is about a lack of awareness of what are future skills needed for its human resources. The companies have to differentiating product to reach the customer need of authenticity and uniqueness, but they also have to consider the difficulties about the digital transformation and the need for transparency, efficiency and quality control. An example of

this “craft and advanced” line is followed by the made-to-measure service offered by some menswear brands, Zegna is an example. The goal is to deliver a true experience to the customers thanks to an interaction with a tailor to create a handcrafted product. To be competitive they need to manage customers’ data and the suit production with advanced technologies. It’s important to have “augmented” workers, advanced craftsmen able to mix the skill of creativity and manual dexterity and the digital technologies and devices.

Important is not only the “smart factory”, but also the “smart network” for the transition of the fashion industry towards the 4.0 paradigm. Specific technologies have been adopted along the supply chain to facilitate its connection to develop a systemic process of digitalization considering two additional 4.0 key principle: *modularity* and *decentralization.* The result is a network of flexible decentralized manufacturing and service units. The system is empowered by real time data exchange, reducing the impact of critical issues on the entire system, isolating the problem into inefficient units. This configuration could be adapted to small and large-scale manufacturing cycles, considering demand variations and quickly adapting the production to market changes, thanks to virtualization and real-time data transparency. Fashion could be more ready than other sectors to welcome this transition. A set of solution are already able to support horizontal integration, like tracking technologies (RFID, Radio Frequency IDentification) or advanced Product Lifecycle Management software (PLM). They link the entire value chain, from supplier to retail or communication channels and follow products until their end-life. The implementation of ‘smart network’ would need a change in the retail approach, it could be implemented a change with augmented or virtual reality. These solutions could enable a reduction of costs, time and workload with benefits in efficiency and sustainability.

Another component of the 4.0 industry model is represented by the very products becoming smart, but at the same time are connected to the world and are trackable for their entire lifecycle [11].

1.3.2 Smart Product

New materials, techniques and processes have found their way into fashion. Opportunities in production and demand planning over the next 5 years will be the 3D design and virtual prototyping, digital printing, automatic/dynamic inbound planning, and radio frequency identification in manufacturing and the inbound supply chain. Burberry was one of the first brand who felt the need to investigate innovation options by starting to stream their own runway shows in 2012. It introduces a 'see now buy now' model, where the collection, online and offline, could be purchased right away. Today their stores do not have any stock available, a store purchase is sent directly from the warehouse to the customer.

The brand provides an online space where designers put up images of the collection they are working on and users can contribute to, advise on and get involved in the design process. Next, each piece is promoted through crowdsourcing, so expert provide the necessary knowledge to create prototypes, oversees the production and finally hosts the sales. Progress has been made in the area of sustainability where new textile technologies and IT helped to increase the efficiency of clothing production. The fashion brands are still slow adapters of smart textiles and wearable technologies.

The smart clothes are garments with technical and digital features in addition to original protective and self-representation functions [13] .The wearable devices include intelligent watches, wristbands, glasses, shoes, clothing, etc. The wearables can capture and communicate data from the body and the environment and be assigned to the Internet of Things (Fig. 4).

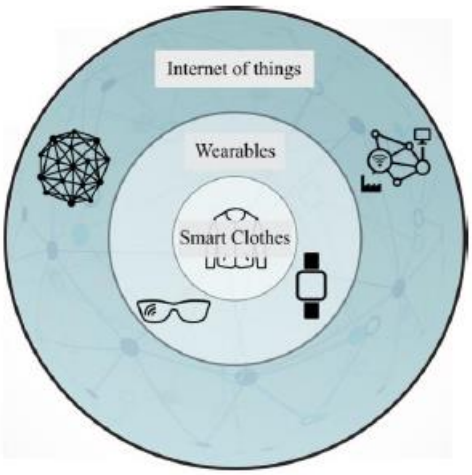


Figure 4 – *Term classification (Source: Oliver Behr, Digital Innovation in the Fashion Industry)*

Industry such as *Adidas, Nike or Ralph Lauren, Google*, are developing products with technical components and digital attributes. The clothes are endowed with technical hardware and digital characteristics, giving to the customers an experience. New materials and sensor technology integrated into cloths that covered large parts of the body's give an accurate measurement of the body's data. These types of garment are not only used into the field of sports, but also in the healthcare system. Several companies are studying to integrate lights, feedback systems and other features into a garment. An example is the start-up *Loomia*, that has presented a product that heat up or glow in a certain situation. Other types of wearable technologies are in the context of augmented and virtual reality section. Here the smart cloth could transform the movements of the person into a virtual world and provide the person who is wearing the cloth some information. In military sector also made research, showing the possibilities and developments in the field of environmental sensors, sensory organs and exoskeleton [13].

Smart clothes can be connected to apps in the surrounding environment and exchange information. This type of communication with the environment could be used by the fashion industry to advance into a digital and service- oriented future.

In order to make intelligent clothes, it must be taken into account that the product has to meet several requirements.

2. The analysis of cad processes

2.1 Pattern SpA

Pattern SpA (Fig. 5) is born in 2000 with Fulvio Botto and Francesco Martorella, both worked in 'Gruppo Finanziario Tessile', deciding to find a company in the apparel sector thanks to their past experience with some international and national fashion firms. The initial idea is characterized by a vertical development of the activity inside the company. Pattern in 2000 started with the development of man collections. In 2005 the company decided to extend the activities not only for the man's collections but also the development and the production of the woman's collections. In 2014 Pattern SpA acquired the 'Esemplare' brand, specialized in the sportswear/urban segment.

Patters SpA started with only the model development and pattern grading, then with the grow of the company, it decided to produce clothing for international brands. Its mission is to develop the entire product lifecycle, from the first prototype to the sample and then their production.

Figure 5 – *Pattern SpA logo (Source: pattern.it)*

The company want to achieve the goal to find the equilibrium between craftsmanship and technology, thanks to the internal workforce and the investment made in the CAD software.

The life cycle inside the company starts with the development, engineering and grading of the pattern, then there is the sample phase. When the sample is approved, the production start. Each year more than 30 collections are made, thanks to a flexible organization that is in continuous development and the checks made in each phase of the product life-cycle give to clients a single service because of the time, quality and flexibility thanks to the vertical organization of the different phases.

Nowadays, Pattern SpA is in an evolution phase in the CAD area, because the company tries always to find a manner to be more efficient and productive, giving a better service to its customers. This progress is necessary because there is a radical transformation of the fashion world, afflicting all the value chain, from the creative phase to the seller. Thanks to globalization and digital technology have contributed to this transformation, shifting the focus point on the market and on the client needs.

Thanks to this evolution Pattern SpA will be able to give an alternative to its international customers, proposing a way to make the typical life cycle of the garment in a more efficient way. [14]

2.2 Analysis of the process: the different stages of product development

The company Pattern SpA in order to develop a collection, makes several steps with as objective the satisfaction of the client.

It's possible to subdivide the entire process in three macro-phases: planning, development and production (Fig. 6). The first phase is managed substantially by the client, who develops several models being part of the collection and all the details that made the garment are also decided, as the used textile, the possible accessorizes, etc. Only a part of them will pass to the next stage of development and be inserted into the collection.

The development phase is divided into: *pattern making*, in which the garment is created with CAD software in sample size for the construction of the prototype, that will be seen by the client for the approval; *pattern grading*, in which a size range is developed for the clothing; and lastly the *marker making*, in which the textile consumption is calculated thanks to a software that positioned the several pieces of the pattern finding the optimal position to have the lower consumption, sometimes this stage is made manually.

The last one is the production phase, where approved clothing of the collection will be produced. For several reasons, like fitting or testing the textile, the client could ask a pre-production for some garments.

In this chapter the development macro-phase will be analysed in detail.

Figure 6 – *Macro-phase division of Pattern SpA*

Patter SpA has Lectra software, not only for the CAD section, but also to manage all the phases of the product life-cycle using the PLM.

The PLM is a “strategic approach to manage design, product data, product manufacture and marketing management. It’s an innovation in terms of creativity and technical design. The PLM is useful for the execution of the NPD” [15] [16].

The PLM manages all life-cycle stages of a product, commencing from market requirement to the disposal and the recycling. PLM is a business strategy for creating a product-centric environment, it is aimed at connecting different actors over the life-cycle of the product from the idea to retirement.

PLM allows the connection of the design software to production and SC management software, taking into account the nature of the company. Thanks to the PLM there is a complete integration of all the software inside the enterprise, having a role in design and other several kinds of activities during a product life-cycle.

The PLM is a culture-generating solution which give the company a unique competitive advantage through its institutionalisation. It’s possible to see the PLM as an interconnected network of dispersed knowledge repositories with are connected using IT solution.

PLM is very useful for fashion firms since it can help to handle the complexity by which they are characterised, in term of supply variability, supply variety, importance of the service provided by the fashion firm to the retailer, need to reduce lead time [15].

Inside the Pattern SpA the PLM software is used to connect all the phases of the product development:

- Creation of the model (Pattern Making)
- Pattern Grading
- Marker Making

Pattern SpA uses PM, a PLM software developed by Lectra. In the figure the screen of a model resume (Fig. 7):

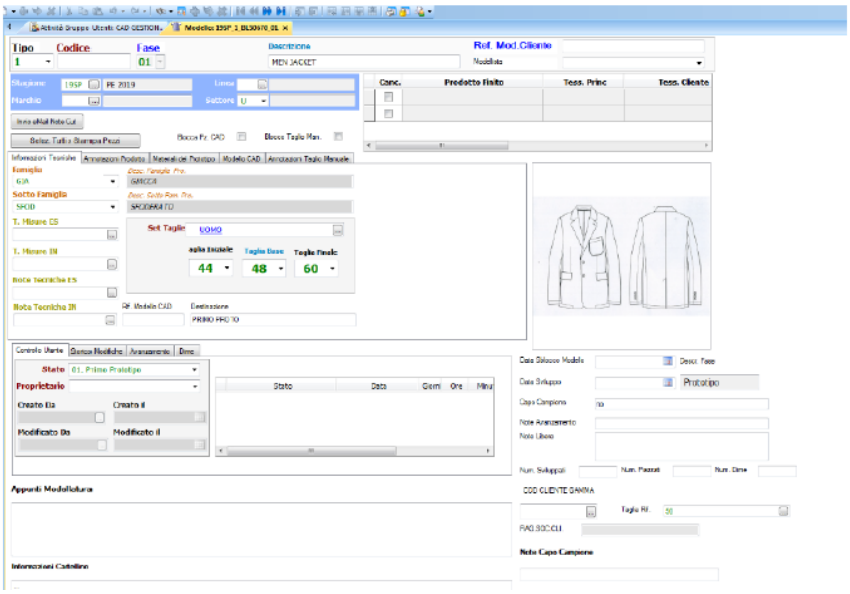


Figure 7 – *Model resume on PM by Lectra*

2.2.1 Creation of the model (Pattern Making)

Pattern making is the process of designing patterns thanks to the creation of templates from which garment and craft items can be sewn. Pattern making act as the connection between design and production. The Patterns maker is characterised by the ability to understand the design/sketch [17]**.**

The pattern makers help to realize what the designers had imagined from the drawing to the final product, they are also known as 'Technical Designers'. When the designer finished the garment design, the pattern maker starts preparing the pattern of the garment. The process consists in several and mutually dependent stages and it represent the first step of the clothing production. The templates are used to track the different clothing parts of similar style against fabric prior to cutting and assembling. In the past the patterns were made of paper. Knowledge of basic geometry is fundamental for pattern making.

A pattern is a help for cutting the fabric which can be sewn together to make a garment. Some companies use the *sloper/block pattern making***,** where the pattern is designed thanks to similar patterns without seam allowance. It could be also basic pattern to develop and design new pattern for clothing. This process is based on standard measurement or by customer measurement [17] [18]. There are two methods for basic block pattern making:

- **Flat pattern technique** is really practical to make. This method manipulates an existing foundation pattern. A basic pattern is created, manually or using a software, and then it is used to create different designs through different stages of manipulation, all based on a particular design. Through the pattern manipulation several pieces could be altered in length and width or change their position. When there are changes, they are marked directly on the paper. This seems simple, but it requires many body measurements and a lot of test fitting [17] [19].

- **Modelling**, also called '*draping on the stand*' involves muslin fabric for fitting of the garment on a dummy body of standard size. This is also called 'toile' and is made from translucent cotton or linen fabric. The pattern maker will model the fabric like a sculptor: it will be smoothed, creased, sliced and pinned until the pattern maker will be satisfied. When the garment assumes approximately the right form, the textile will be marked with lines, using a pen or a pencil, grade marks and annotations about which piece is part of the garment, and then it's removed from the mannequin. This method is largely used in high-class fashion, because it's simple to understand. Modelling requires more time with respect to the flat pattern technique [17] [20]. (Fig. 8)

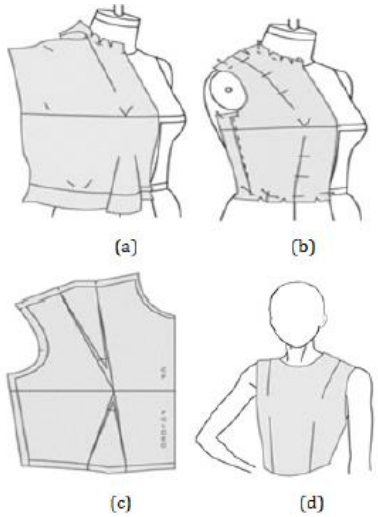


Figure 8 – *The draping process from 2 D muslin to finished garment. (a) and (b) Use of muslin to drape front bodice; (c) Finished pattern with seam allowance; (d) Finished garment. (Source: Dibyendu Bikash Datta and Partha Seal; Various Approaches in Pattern Making for Garment Sector)*

Another method is the **computerised pattern making**, and inside the company Pattern SpA are use this type of method with a Lectra software called PGS Modaris (Fig 9). Creating a flat pattern using CAD is the best way to design the pattern with respect to all the other techniques when the pattern maker becomes familiar with the environment is working with. Digitalisation of manual pattern and using for production is widely distributed [17].

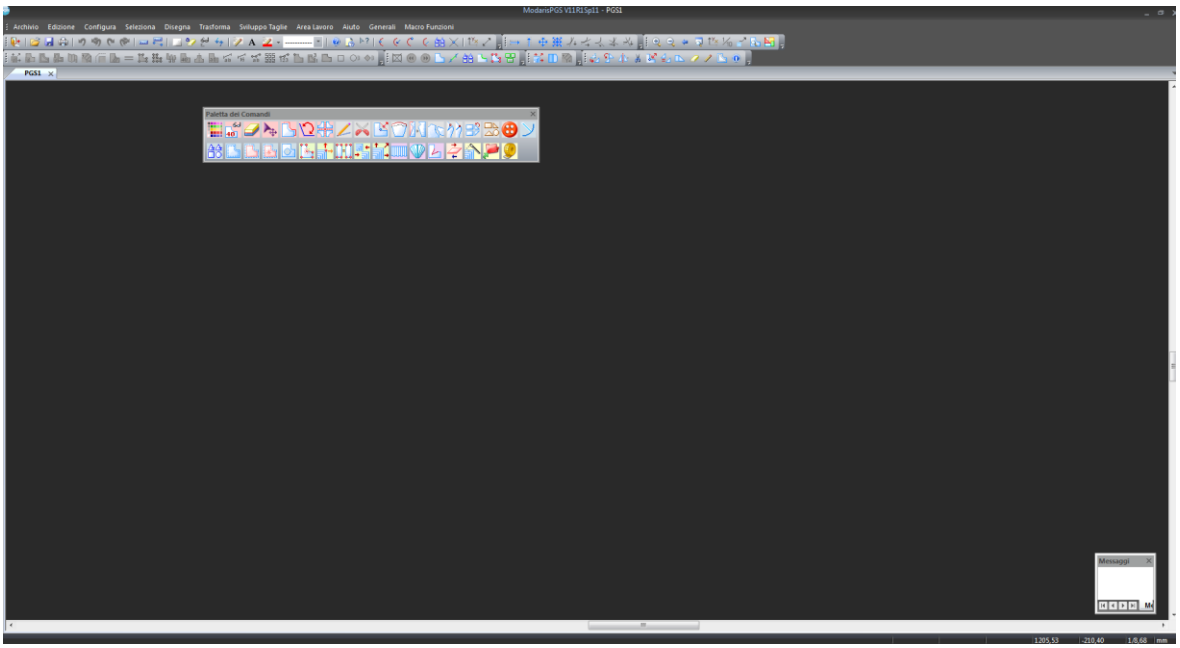


Figure 9 – *PGS home by LECTRA*

The pattern maker works using the table of measurement given by the customer or with table of measurement standard. The designer uses geometric designs based on several shapes and lines to create patterns. The pattern maker could make changes if necessary and correct patterns for the next steps like pattern grading and maker making.

The platform used is useful for making patterns that are repetitive, because inside a database exists the standard patterns. Some pattern makers draft on hard paper and then use the scanner to convert the pattern into a computerized format. If there are some changes to make, they will do it on the pattern on-screen.

The main technological features could be distinguished into “pattern design systems” and “pattern generation systems”. The first ones accelerate the productive process and improve accuracy. The pattern maker drafts the block on the computer, then constructs clothing pattern by placing all the block patterns in current use. The second systems create the pattern thanks to automatic pattern components of a pattern design system [17].

CAD software systems are several and the best come from *Lectra Systems, Gerber Technologies, Tukatech and Optitex.*

CAD systems can be used for several fashion design processes, not only for the pattern making. Thanks to the CAD system the time spent for the creation of the patterns is reduced, and so the efficiency increase.

A pattern maker, following a set of instruction, is able to understand a design by drafting it through pattern pieces to create a style. This type of process is known as *pattern drafting*. The body measurements are transformed in lines and curves, in order to determine the overall sections of the pattern pieces. The pattern pieces represent the sections of the clothing and inside them there are information about size, balance marks, pocket, placement of button, notch mark, seam and hem allowances (Fig. 10).

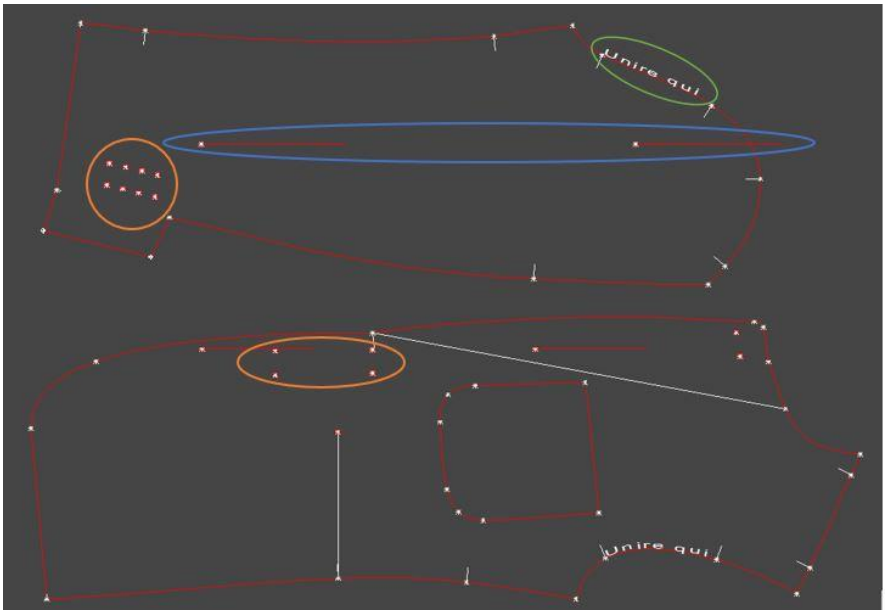


Figure 10 – *Example of marks, in orange are buttons an in green some notes.*

Pattern making, as written before, is a link between the design and production. A correct pattern helps to make a proper sample and it has some information of sawing allowance, grain line and fabric cutting direction in order to eliminates fabric wastage [18].

2.2.2 Pattern Grading

Pattern grading is the process where patterns of different sizes, from the smaller to the larger, are produced from the original pattern, without changing the final result of the sample size. This process can be made manually or automatically with a CAD system software.

All the garments are designed taking into account a sample size, and then the other sizes are developed changing the measurements. In the apparel industry there are a lot of way to change the sizes of clothing. They depend by the gender, male female or kids, and by the country membership. The different type of how the measurement are taken are collected in different size chart. The size chart is not unique, and a size called with the same name but that belonging to two different size charts could differed for the measurements. The companies always make an analysis of the sales in way to better understand the customer typology and then change the measurement of the sizes.

Patterns at the beginning are made in one size, called sample size. To produce garment that fits different bodies and sizes, the patterns measurements will be increased or reduced in order to create a range of sizes. Depending on the company, each size is characterized by different grade specifications and size specification differ from manufacturer to manufacturer [18].

The aim of grading is to increase or decrease proportionally the size of a pattern, while maintaining shape, fit, balance and scale of style details. It exposes the fact that individuals of different sized are proportionately different. Each company sets a predetermined grade specification, or rules. There are three different methods of pattern grading: **cut and spread**, **pattern shifting** and **computer grading**.

The **Cut and Spread** (Fig. 11) is the simplest method, and this is the basis of the other two methods. The pattern is cut, and the pieces are spread by a certain amount to grade up or overlap the pieces to grade down. The tools needed are only a pencil, tape, ruler and scissor.

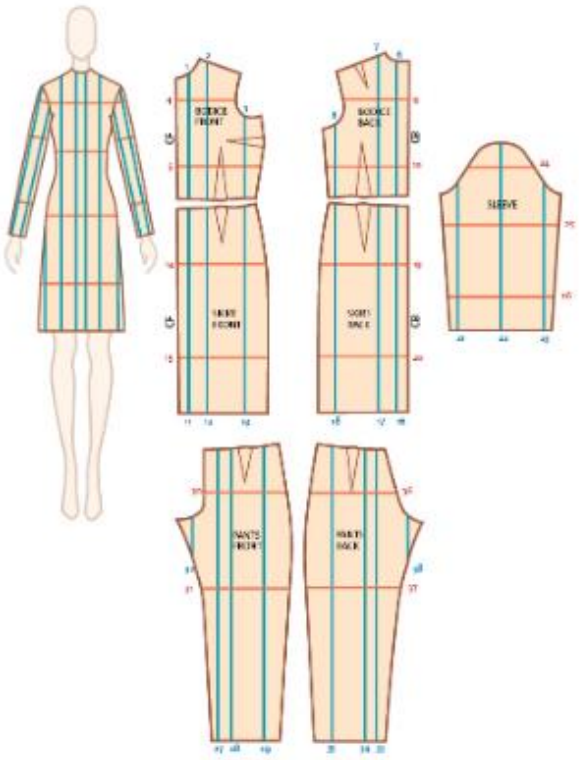


Figure 11– *Cut and spread pattern grading (Source: starkfashionbd.blospot.com)*

The second method is the **Pattern Shifting (Fig. 12)**, the all dimensions of a pattern are increasing by moving them around at a constant distance in four principal direction. After the dimension of pattern is moved, it must be redrawing the outline in order to produce the same result obtained in the method seen previously.

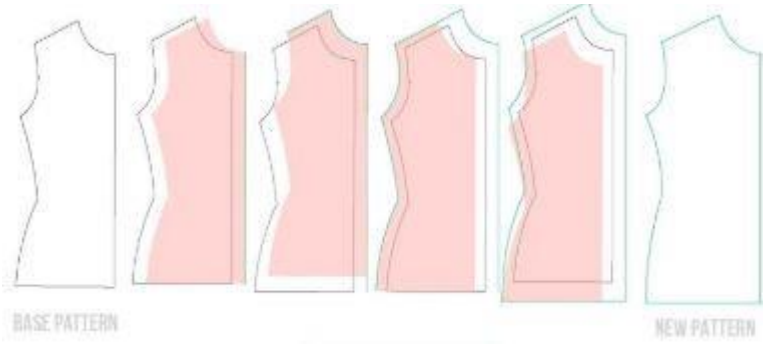


Figure 12 – *Pattern shifting method (Source: starkfashionbd.blospot.com)*

Today most manufacturers practise the **Computer Grading** (Fig. 13) using CAD systems, it's the most recent development in grading technology and it's also the faster method. This method takes the processes seen previously and digitizes them [21].

Inside the company Pattern SpA is used PGS Modaris, by Lectra. The pattern grader prints the several pieces of the pattern and ordered them to understand what will be graded, typically the similar pieces are placed near to be more organized.

The pattern grader at each of this parameter is cross-referenced by a grade-rule table stored in the computer, which enlarges or reduces the pattern automatically according to the predetermined direction. If a similar pattern was already graded, he will go on the database to search this pattern in order to be more efficient and reduce the errors and the time of pattern grading. The final output must be the same for all the sizes, the grading must be harmonious.

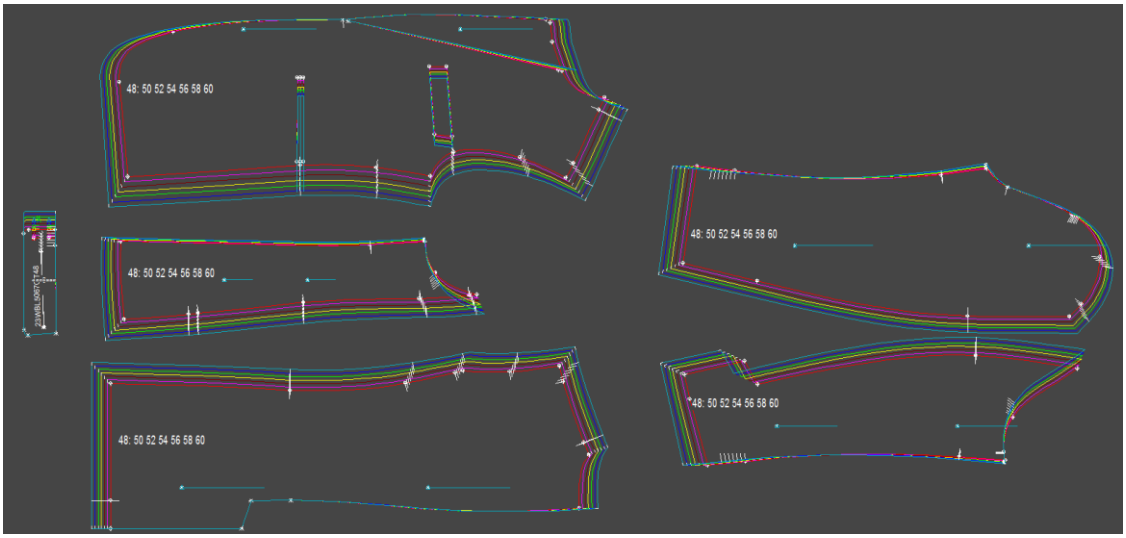


Figure 13 – *Pattern graded*

When the textile is cut for making garments, it's important to make sure that fabric is not subjected to any additional stress during the cutting. Before cutting the textile, it's important to make sure that the shrinkage is minimized. If the fabric is subject to shrinkage, this will be contained in all patterns of a garment made with that fabric. This shrinkage incorporated in patterns could be along the length or with respect to the width depending on the type of fabric.

It's important that the original shape and balance of the pattern is not distort by the shrinkage adjust. In order to get the correct fit and drape of a clothing and the correct measurement, it's important to make the shrinkage incorporation [18].

2.2.3 Marker Making

Marker making is one of the most important tasks in clothing manufacturing industry. Accurate marker making helps to reduce fabric wastage which ultimately reduces the cost of making the cost of making the garments. There are different types of marker making method used in readymade garments sector, which are explained in this article. Marker planning is a creative, intuitive and conceptualizing process rather than a technical one and there is no final result for a marker planning. The output is to achieve the shortest marker taking in consideration the practical and technical constraints. These constraints are related to the fabric characteristics and the design requirement in the finished clothing, the cutting quality and the production planning.

There are two types of marker making, the **manual** and **computerized** method. The first (Fig. 14) is the oldest and traditional method. In this process pattern maker makes all the pattern pieces manually and after that fabrics are spread on cutting table and set up all pattern pieces directly onto the marker paper. The marker planner works easily by moving around the full-size patterns until an acceptable marker plan is obtained. The characteristic of this method is that all the patterns are in real dimension and the tables are arranged to no tilt. Then mark by pencil or pen [22].

Figure 14 – *Manual marker making (Source: fashion2apparel.blogspot.com)*

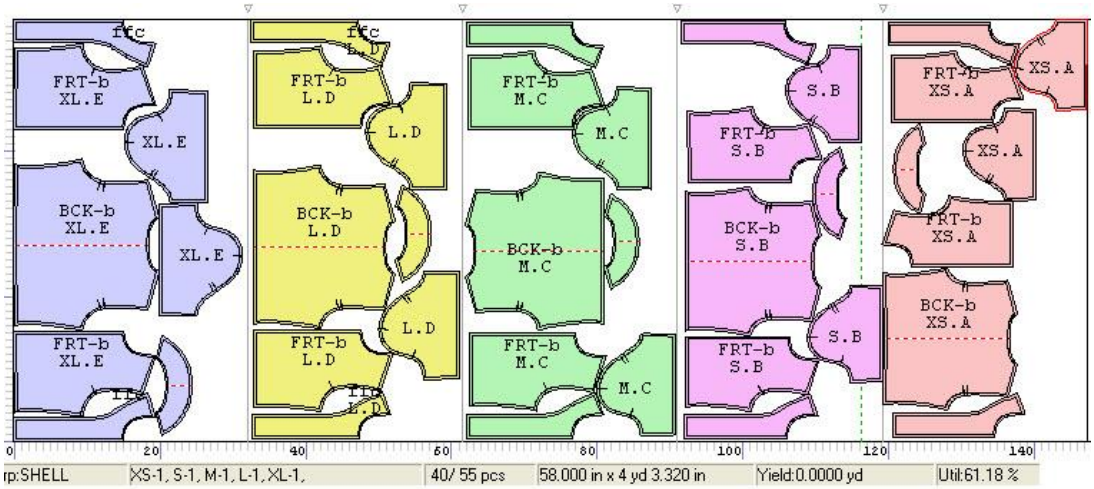
The **computerized marker making** is the best and popular method and gives the higher efficiency in placement of pattern pieces in way to reduce the waste of material.

The software used in Pattern SpA is Marka by Lectra and it's used for the realization of the marker used successively as input for the automatized cutting machines. Each textile is characterized by some measurement, the height and the length. It's important that the several pieces of patterns are placed in the right direction, following the texture guidance of the threads, because otherwise the clothing could be not fitting in the right way. The direction of the threads is important because when the pattern maker is drawing the different pieces, he has the duty to generate a reference axis with respect to the cutting of the pattern.

The computerised marker making has to take in consideration the manual cutting and the computerised cutting, the optimization of the cutting and the typology of the textile.

For the automatized cutting, the marker making is made with CAD software, in the software the information about the textile are inserted and then the several pieces of the pattern are taken and placed virtually on the textile. A safety measurement is defined that represents the minimum distance between two different pieces, in way to not have two pieces in overlapping. The overlapping could let to the fail of all the cutting pieces.

If the textile is simple, without printing, the marker making is made automatically by the software, that tries different combination and then decides the optimum solution to have the higher efficiencies and the lower waste of the textile (Fig. 15).



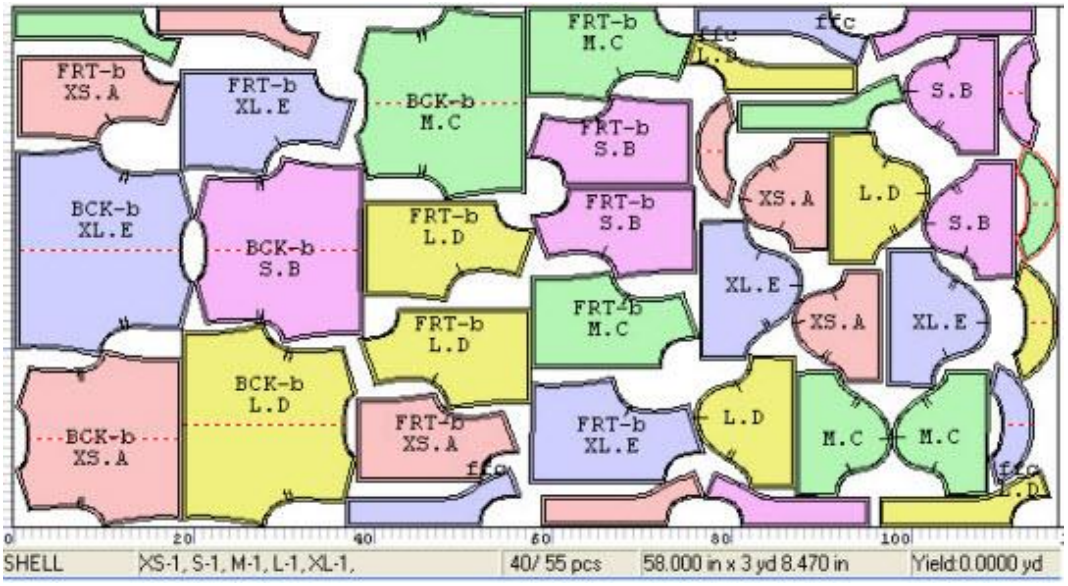


Figure 15 – *Differences between inefficient (top) and efficient (bottom) marker. (Source fashion-incubator.com)*

If the textile presents prints or a particular texture, it's important taking into consideration the reference made on the CAD software to have the information about the several characteristics of the textile in way to have the right placement of the different pieces. Obviously when the textile has a lot of particular with respect to the simple textile, the usage will be higher and also the waste increases. When the textile is complicated the cutting will be done manually.

When there are these particulars is required from the clients that the texture is continuous in every part of the garment, an example is a print on the garment that must be always centred or that has the same proportion with respect to the size or that the print has always the same position with respect to the different pieces that compose the garment. Another example is the tartan follows a precise rules on the clothing, so the texture must be followed in all the part of the garment, this is the *check matching* (Fig. 16).

Figure 16 – *Example of check matching in a jacket.*

The problems of this type of textiles increase the difficulties of the pattern grading and the marker making stages, because it's necessary understand and plan the way to produce in the best way the garment and satisfy the request of the client.

These problems are simplified by the CAD software, but experience and the analysis of the technician is essential because nowadays is not possible that the process is totally automatized.

For the manual cutting the marker making is made by the CAD software inserting the characteristics of the textile and the 2D pieces are places virtually on it.

3. Ideal 3D platform analysis

3.1 Actual Situation

Before to start to describe how the full 3D could be applied in the apparel industry, it's important to analyse how is the actual process for the realization of a clothing, to better understand why there is the necessity of a new paradigm.

The initial step is the development of the cloth by a designer's team and the output is a 3D sketch, considering the designer idea or the concept that they want advance, then the 2D sketches will be draft. After this step, the sketches are sent to the supplier for the clothing engineering. The process starts with the pattern maker, who interprets the idea of the designer and creates the pattern, that is the union of elements that made the clothing. Successively, the garment is assembled by craftsmen and sent to clients to test how it fits on mannequin and the other particulars, an example is a writing on the clothing if it's in the correct position; starting a series of steps that find an end when the client is satisfied. When the clothing is definitely approved by the client, the pre-production starts, and the sample produced will be considered in all the other steps of the product life-cycle (Fig. 17). At the end the entire collection will be ready to be produced [23].

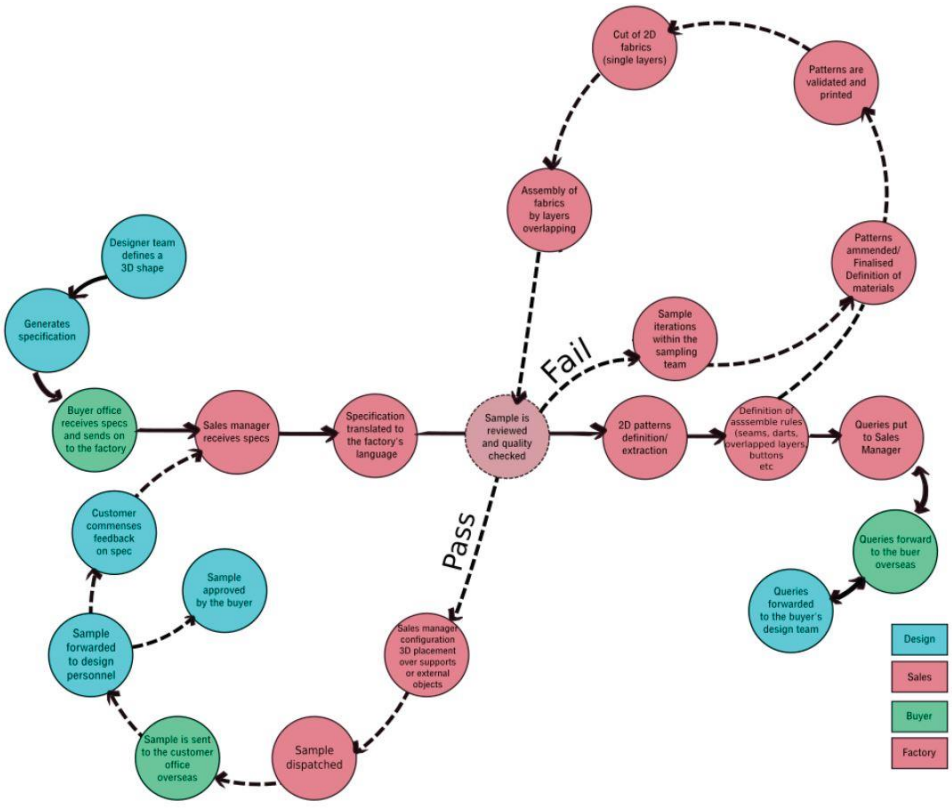


Figure 17 – *CAD 3D virtual process*

This process treats a large amount of data along all the value chain, indeed the information flow doesn't pass only through the company, but all the actors of the value chain could draw the informations and the data generated among the product life-cycle. It's possible to deduce that more people are interested in the value chain, more difficult will be the communication network.

It must be taking into account that the producer, in order to reduce costs and maximise the revenues, relocates the actors that compose the value chain, far away one by each other, in location where the costs incurred are lower.

During the product lifecycle must be always present a physical sample because the several actors have to better understand how it's made, understand its constituents and all its layers, how it could fit and maybe the process of some particular component. It's fundamental that the garment is sent to all the actors, who made the different steps of the process of the supply chain, to be sure of the correct realization of the product.

There are to consider also the problems of fitting, in fact until the clothing is not produced and wore, it will not be sure that all the passages done previously are made correctly. From that, there is the necessity to produce not only the sample size, but also the smaller size and the larger size. The consequence is an increase of cost and time required.

Considering the problems of the apparel industry, like the waste of material and the environmental footprint; there are some innovations that try to reduce the lifecycle time of the product and also the cost incurred for the realization of that. The apparel industry is backward with respect to the other industry sector, like automatic aeronautic, etc, that accept the technology innovation and consequently increase their efficiency and productivity. This occurs because there are some aspects that cannot be automatized, an example is the textile, that depending on the material with which it is made, has different characteristics and reacts differently depending on the process. Also, the apparel industry is strongly linked with the handmade production and it is subject to the largely amount of measurement that characterized the different conformation of the bodies [24] [25].

3.2The ideal full 3D platform: how it will work

Fashion industry would be a world that prides itself in being organic, creative and spontaneous, far away from what derived from engineering and technology [26]. In last decades, with the birth of fast fashion and the evolution of technologies, this sector is evolved using knowledges developed for apparel industry.

Nowadays there is the need of a faster design technology, that's because customers expect new collections more and more often. It could be the possibility to have a system that exploits a 3D software changing the paradigm used today and will facilitates the process from simple sketches to interaction with customers.

An option could be a platform that exploits the actual technology, upgrading it and integrates the 3D technology. The platform has to be conceived taking into account all the stages of the product lifecycle and how the problems of each stage could be minimized with that. This could have several features, that will affect the process from different perspective, in order to get it more efficient and consequently changing the actual paradigm.

First of all, the platform has to be conceived with a user-friendly layout, so the several actors that play in the value chain have to learn how to use the software in not so much time, due to the short time required by the client to satisfy the order, consequently the platform must be easy to use. The several commands that are used in each stage must be clear and immediate, this is really important, because not all the people that act in the product life cycle are at their ease with the technology, and so they require time to understand how the program works and insert that in their product lifecycle routines.

During the product lifecycle, all the players need to visualize the clothing and understand how it fits on the body and understand which components make it up. In the platform there will be several databases, one of them will be for the measurement of the dummy body, due to there will be the possibility to customize it. In fact, each brand has different measurement baseline, even if the garments have the same size, but the body structure is various. The database will have an unlimited number of bodies, in order to satisfy the requirements of the brands; in fact, the software will be used from the designer, who draws the clothing, as well as from the marker maker, who will have a clear vision of how the textile will be placed within the clothing. This database could be constructed thanks to some collaboration between the main software houses, with the scope of having a larger range of bodies. The

companies could also use the body scanner in order to achieve the measurement of various models for each brand without be dependent from others.

There is also another database, about the standard pattern pieces already graded: at the moment exists something similar to this database, but really simple and not categorized. The database will contain all the pieces of pattern already graded and with all the information about of sawing allowance, grain line and fabric cutting direction. This database could be used by the pattern maker, and the pattern grader, who will construct and grade the pattern starting from a basis.

Another database is about materials and accessorises used: it's necessary to have a clear image of how the garment looks without using a physic prototype. At each stage of product lifecycle, the image of the dummy body wearing the clothing will be similar to the real one. The image on the screen will be able to visualize all the details of the textile, an example is if it has repeated images, the software will be able to reproduce in detail that, also the accessorises will be well defined, in order to understand how the clothing will be at the end. The platform will be able to have a library of textiles and accessorises, the databases will be constructed by the supplier, depending on the type of product supplied, they will insert the technical information of that product.

The last database is about the past markers made: the textile used in this stage of product lifecycle is huge, in fact there is a large waste of material and there is the necessity to reduce the amount of textile used, not only to reduce the costs, but also to reduce the carbon footprint. There will be an image on the screen where there is the dummy body wearing the clothing with the textile and the marker maker will be able to change the position of the textile, in order to satisfy the requirement of the client. The software is able to source in the database and to find which combination of the pattern parts will give the less consumption.

Important feature of this platform could be a link between the Product Lifecycle Management software and the platform itself: the communications, inside the company and between the company and the other actors of the value chain, are not always simple and sometimes could be cryptic. The PLM software integrated with the platform will have a common cloud between all the players, which will have their PLM software. The communication between the two programs will be possible because of interactive table in the platform that will update the information in the PLM software. When the operator, who

could be the pattern maker, pattern grader or the marker maker, is working on the platform, inserts or modifies the data, that's are automatically updated on the PLM software.

It's important that in the platform there is the possibility to have the double screen, with the vision of the dummy body in 3D and the vision of the several pieces of pattern in 2D, this because at the moment, it's not used the 3D software at all of its possibility. During the pattern making stage, the pattern maker could observe on the mannequin the garment and all its layers, sent by the designer. That's because when the designer was drawing the model with the platform, he could be able to develop more than one layer. Successively he could develop the several pieces that constitute the pattern. It's possible also to build the 3D mannequin with the pieces of pattern to match if what is constructed by the pattern maker and what it's sent by the designer. In the pattern grading stage, the platform could give the option to see the clothing in 3D and the pattern created by the pattern maker. The pattern grader has the possibility to see the mannequins in different dimensions, because as it's seen previously, the pattern grader creates the clothing in different sizes, taking into consideration the brand and the country. That's possible because the platform could give the option to customize the dummy body and construct the garment in the sizes required.

Changing the pieces of pattern in the screen where there is the 2D pattern, automatically the garment in 3D changes and in this way it's possible to better understand the final result of the garment and check if the same aesthetic of the sample size is fulfilled. The platform could work even if the pattern grader wants to work on the 3D side, so if the garment is modified on the mannequin also the pieces of pattern will be modified automatically.

The possibility to have both the screen in 3D and 2D could be used also by the marker maker: actually, if there are models that presents a textile with particular frame or embroideries, there are several steps made to facilitate the stage, but not are always precise. In fact, the platform could be able to show on one side the mannequin with the desired layer of the garment and on the other side the virtual textile and he could see how the position of the textile in case of it has particular frame.

An important feature of the platform will be the format of the output file: at the moment a unique format for the 3D file doesn't exist, it exists a unique file for the 2D files, called DXF, and so there are technical problems about the quality of the 3D file exchanged between the several actors of the value chain, first of all between the brands and its suppliers that develop the engineering and production stages. The platform will generate a file that could be

exchanged with the other actors without loose quality or details because of they are using different several operative systems, in order to have a clear image of what is made previously. This standard format will be developed by several the software houses, in order to make easier the exchange of informations [27].

In the next sections will be analysed the impacts of this platform on the apparel industry and its limits.

3.3 Full 3D: how the change can affect the company

An ideal full 3D platform could change substantially what is nowadays the product life cycle of a collection and obviously, of a single garment. First of all, this type of platform will be helpful for designers, in fact during the styling phase they have no idea about how the garment will fit, until their prototype is finished.

The 3D platform could be used during the early design stage and it would be a help to take decision about style line, size of garment or also to have a sharper vision of style, understanding which textile is better to use and taking into account the type of garment and also the body that the designer has imagined. In fact, the software, as it's explained before, will have inside of it several databases in which suppliers will insert informations about physical and chemical characteristics of textiles. It will be present another database of bodies, in which data of several country and consequently of several bodies are collected (Fig. 18).

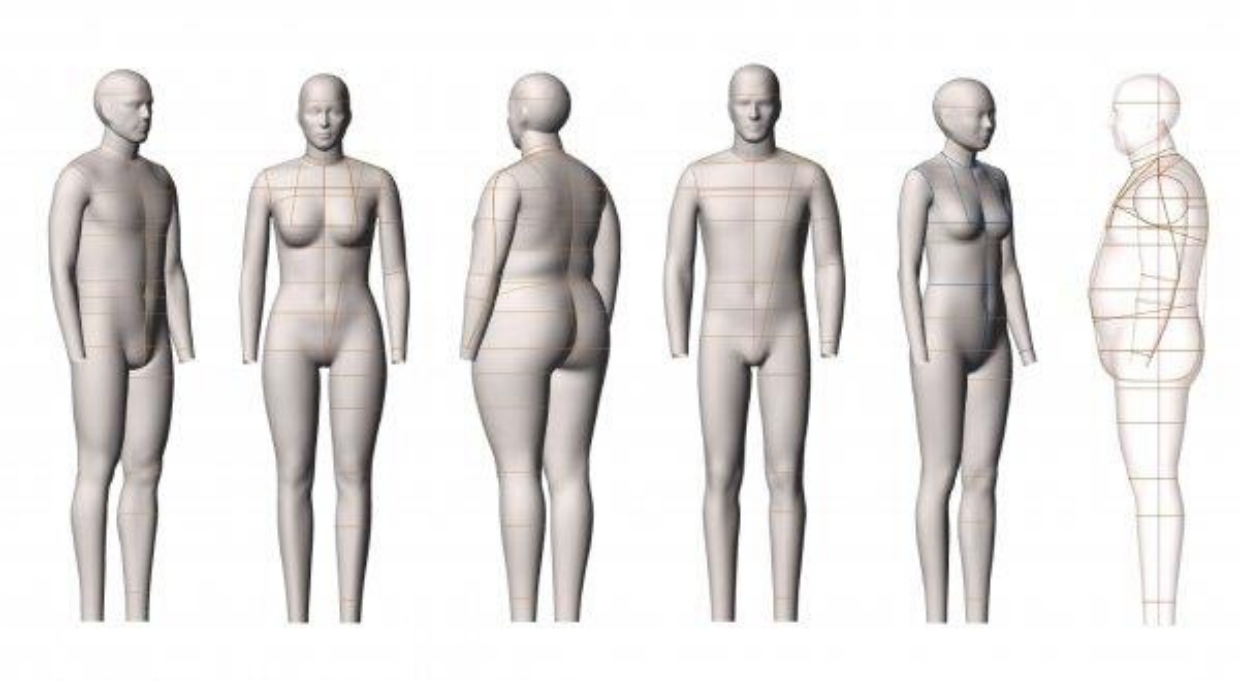


Figure 18 – *Example of different bodies shapes in 3D (Source: sourcingjournal.com)*

In this way the software could give the possibility to see the shape of textile and how this will fit a certain type of body and change them until his satisfaction.

This software will be based on video-games and movies codes, in order to have a realistic vision of design, it also produces virtual creative spaces and options to help the designer to

reduce waste and to cut costs, finally the software brings the collection to market in less time.

If designers could work with this ideal platform, they would introduce a new collection faster, without going through 2D technologies, wasting a lot of time, and consequently saving time and reducing the time to market.

Moving on in the product lifecycle, it's possible to analyse how the platform 3D could also change the work in the pattern making stage. The pattern maker has to create the 2D pattern of the garment in sample size, in order to have the several pieces that construct the prototype of the clothing, then it could be shown how the garment fit. The pattern maker with this platform could not only have the possibility to see immediately which garment the designer has imagined, but he will also see all its layers without interpreting the sketch. That's because the designer has previously drawn the clothing taking in consideration all the layers that he has imagined composing the garment. The pattern maker has also the option to parametrize the dummy body in the platform, to be aligned with the measurement required by the client. The pattern maker could work looking the mannequin and after having developed the pieces of pattern, he could construct it instantly on the 3D dummy body. It's also possible to make some variations directly on it, through dedicated controls, and if the clothing after the prototyping will be accepted by the client, it will be inserted definitely in the collection. This will reduce the time required before there was the platform.

As written before, inside the platform will be several databases, that are not only about the textile and the bodies, but also about the standard 2D pattern that constitutes the garment. Inside each standard pattern will be all the information about of sawing allowance, grain line and fabric cutting direction. In this manner, he could save time wasted in interpreting what the designer has drawn, and he has not to construct the pattern starting from nothing and putting all the fundamental pattern information. So, the pattern maker is starting from a pattern already existing, modifying it to have the desired pattern that the designer had drawn.

In the platform will be a connection between the 2D software and the 3D software, thanks to the double screen of the platform, it's possible to observe simultaneously the garment in two dimensions, look at only the pattern and 3D, where the clothing is dressed by the dummy body. In this manner the pattern maker meanwhile makes some changes on the dummy body in the 3D platform, he could see immediately how the 2D patterns are modified. This feature of the platform will be helpful because he not only could see immediately the modifications

on the garment, but he could also understand how the changes affect the textile yield. From pattern making stage, the processes are not made by the client, but by one or more suppliers who do the engineering part and the production. The several processes of engineering part are linked together, by a product lifecycle management software and the other actor of the value chain, like the client or the several laboratories where is done the production, are not informed about the status of the garment in real time. That's because the PLM software is only at local level, it not exists a cloud that gives the possibility to visualize by all the actors of the value chain in real time the progress of the item. With the evolution of the actual system, so with the 3D platform, the several step will be linked together in real time through the PLM software for every actor of the value chain, in order to be updated of the action made on the clothing.

The integration between PLM software and the new platform has also the feature of the interactive size chart, in this manner when the pattern maker is changing some measurement the system identifies the variation and registers the new measure on the dedicated section of the PLM software. Similarly, in the patter grading stage the data developed from the grading will be registered automatically in the PLM software, thanks to the interactive chart. This allows to a decrease of errors made after the stage of pattern making or the pattern grading because an oversight in changing the size chart inside the PLM software.

The platform has also the option to integrate with external system, this because the several actors could not utilize the same operative system. That is achievable because of a standard format able to transfer the 3D file without having penalty on quality, even if it's used a different operative system. This feature gives the possibility to have detailed virtual samples to be viewed and altered by professionals, although they are dislocated. This allows to a good integration of data flow between different systems.

When the pattern maker has done the pattern pieces in sample size, there is a phase of prototyping and fitting. Thanks to the platform 3D these stages could be done in less time, as a result of real time images with a specific style are done without trials of shipping patterns and sample. The 3D sample grants access to every actor who contributes to the apparel-making process and they could also allow to detailed changes to digital pattern. The 3D prototyping permits to send immediately the virtual prototype and the client has a prompt reaction of the clothing. The client could agree to the virtual prototype file created and going to the next step; or send it with the changes that are to be made on the garment. That's because, as written before, there is a standard format that could be opened and modified also

if the receiving has a different operative system. Thanks to the opportunity to develop virtual prototype is possible to reduce the number of physical prototypes thanks to the generation of realistic and accurate samples on the platform. The benefits using this feature are: a reduction of cycle time, because the waiting time for the approval would be reduced; ultimately a decrease of cost concerning the production of the several physical prototypes.

There are also effects using the platform on the fitting stage. The fitting at this moment is done modifying the physical prototype marking on this the changes to be done and then another prototype will be made-up, the process is repeated until the client approved the garment. The platform could modify these steps going to reduce the time required. The high definition of the program concerning the textile and the accessorizes is due to the data inside the database about the physical and chemical characteristics of textiles. The mannequin in the screen could move and could show how the textile react with the movement of the body and how the textile fit the model, it's possible also made a virtual runway show to see the garment moving.

Thanks to these characteristics using the 3D program during the fitting phase, if the client wants to do some adjustments, they could be made in real time in order to have an instantly comparison between the new and the old prototype.

Another stage could be affected by the new platform: the pattern grading. The pattern grader constructs a size range after the clothing has passed the prototyping stage. He has to take in consideration some characteristic parameters depending by the country and by the brand of clothing, and he has also to consider that the garment in all the sizes must have the same aesthetic level. The pattern grader has to do several iterations before to find the optimal combination of parameter that grant the aesthetic.

The platform, being divided into two different parts, gives the possibility to see how modifying the pieces of pattern in the 2D view, this change in the 3D view. It could also give the option of customize the dummy body, with respect to the size, the brand and the country, in order to have the body similar to what is ideal for the client. Thanks to the databases, the platform elaborates the information about the textile chose for the garment and when the pattern grader makes some changes on the pattern piece, the textile will be adapted with respect to the dummy body taking in consideration its physical and chemical characteristics. Due to the high definition of the image, the pattern grader has an effective idea of how the clothing fit on the several bodies.

Moving forward in the value chain, it's possible to define some advantages when the product has to be placed on the virtual textile, in the marker making stage. The marker maker has to obtain the minimum consumption of the textile for the single garment to have an efficient production. In the marker making stage, there are some problem due to the fact that clothing could be made with a particular textile. This has to be placed considering some rules gave by the client, an example is when there is a figure on the textile and it is recurrent, it has to follow a certain direction.

The platform gave the option to place in the virtual textile the motif fabric, in order to help the maker into the placement of the several pieces of the pattern, because in this moment the marker maker uses methods that are cumbersome and take a lot of time. It has also a database linked with the PLM software, where all the placement made are stored, in order to make the marker making stage more efficient, giving the possibility to forecasting the consumption of textile used for the future models.

The high definition of the dummy body wearing the clothing gives the possibility to upload on several e-commerce the option to insert the 3D images, in order to satisfy the customers because he could see how the garment fit on the dummy body of his size and he has a clear idea of how the model could be wore on himself.

It's important to consider how this change of paradigm could affect the impact on environment. The apparel industry is second most pollutant industry, this because is a particular business that includes several steps, from the preparation of raw material, the setting up of the textile to the disposal of the garment. Nowadays the fashion carbon footprint is tremendous, it must take into account the pesticides used in cotton farming, the toxic dyes used in manufacturing, the transportation of the products and the amount of waste when the clothing is created, especially when the pattern is cut manually [24] [28].

Thanks to the platform, with the 3D sample could be possible reduce the footprint, changing the process and becoming it more sustainable. It could be possible because the number of samples produced could be lower, so less material will be used, and waste and ultimately less hazardous chemical used.

3.4 KPI of Full 3D

After having talked about what could be the positive effect on the apparel sector using the ideal platform, it's important to quantify the impact of that. At the beginning, in order to measure the effect it has, it must be clear which type of garment shall be chosen for the analysis. Once the type of garment is chosen, the season, summer/spring or autumn/winter, the year and the brand will be decided. The data used to quantify the impact, are provided by the Pattern SpA.

The analysis is about several models of trench of the most important client of Pattern SpA, of the last spring/summer 2018/2019. The data are extrapolated thanks to the PLM software used to communicate between the several departments of the company. First of all, all codes of the trench are extrapolated, both for woman and for man, and the result is 32 models (Fig. 19). Then, the information about the material used and the cost incurred for the prototypes and for the *toile* are extrapolated; the toile is a garment made with a very cheap textile.

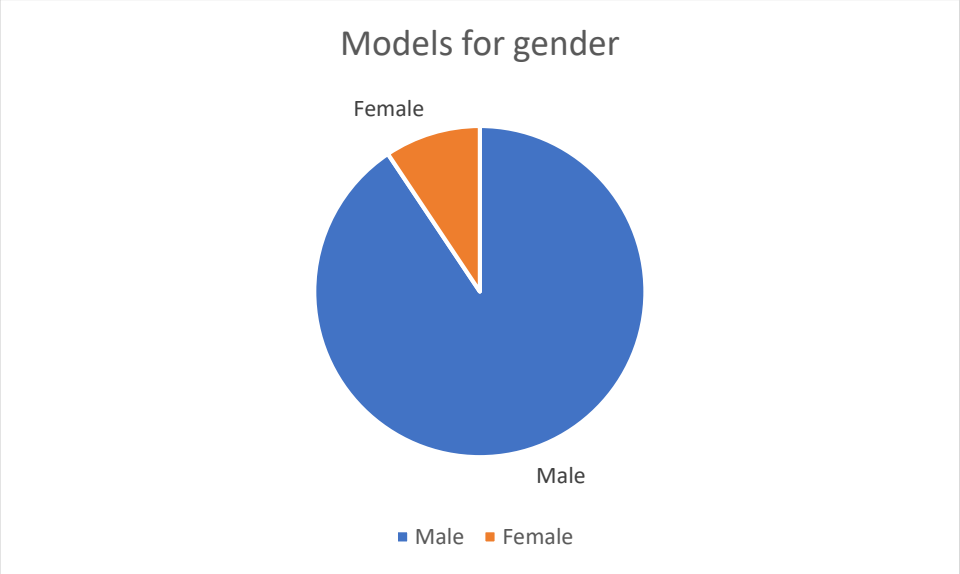


Figure 19 – *Subdivision between the several model*

The analysis is made taking into account the first prototype, the toile and the prototype used for the runway show. All the prototypes are made only in sample size. The prototype used for the runway show has to be produced anyway, so this step cannot be substituted by the platform.

Three cases are analysed: the actual situation, the possible situation without using both the toile and the first prototype and then the situation without using the toile.

- First case: actual situation. Nowadays, the Pattern SpA are producing for several models, depending on they're difficulty, the muslin and one or more prototypes, before producing the garment for the runway show.

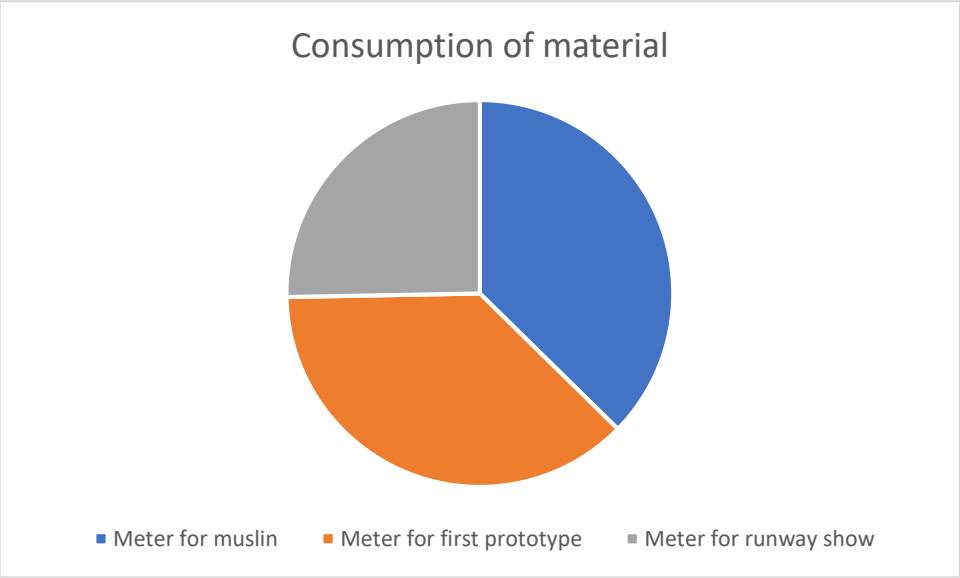


Figure 20 – *Consumption of material for the prototyping stage*

The consumption (Fig. 20) for the production of the toile and the first prototype are the same, but after the evaluation of the client, some changes could be made about the material used, because of the client wants to use a cheaper material, or because the model is not approved and not passed to the next step.

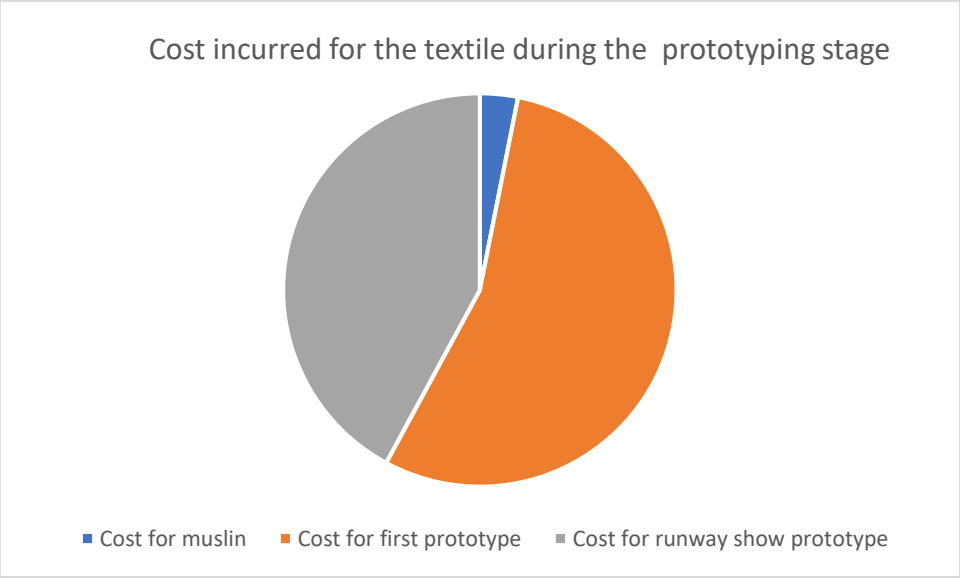


Figure 21 – *Cost incurred for the textile during the prototyping stage*

The cost incurred (Fig. 21) are mostly for the first prototype because the client could change his mind or because he wants a cheaper textile. The cost of the muslin is really low, in fact the cost of the textile used is really low, that's because is made only to better understand the style of the model.

- Second scenario: if toile and first prototype are not produced. Thanks to the platform, the muslin and the first prototype could be not produced because of the high-quality definition of the garment on the video. The material will be used only for the production of the runway show prototype. This reduction of consumption will impact not only the volume of material used (Fig. 22), with a saving of material of 74.71% with respect to the first scenario.

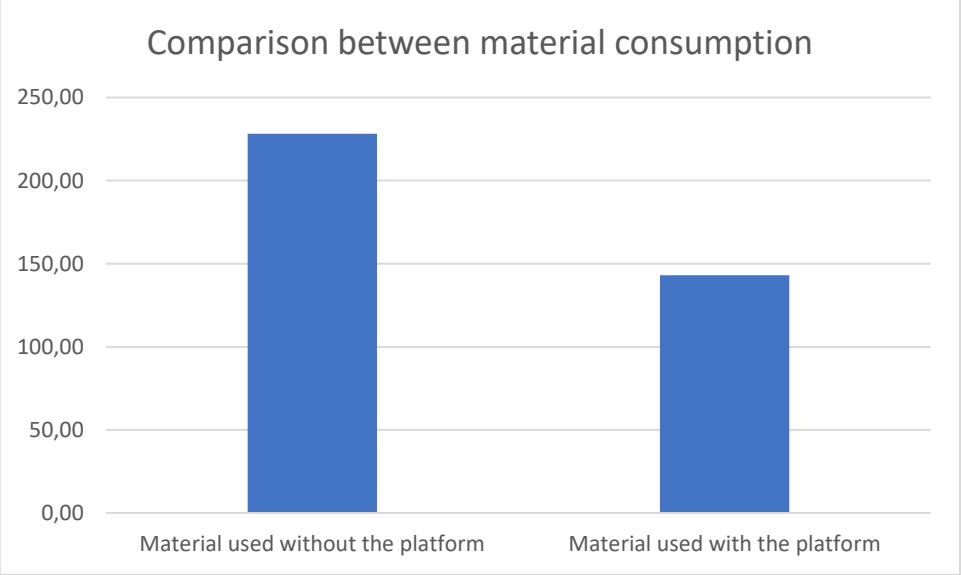


Figure 22 – *Comparison between material consumption*

The cost incurred (Fig. 23) within using the platform will be lower, because of the first stages of prototyping will be done with the platform and only the runway prototype will be produced. It could allow to a 57.91% of saving.

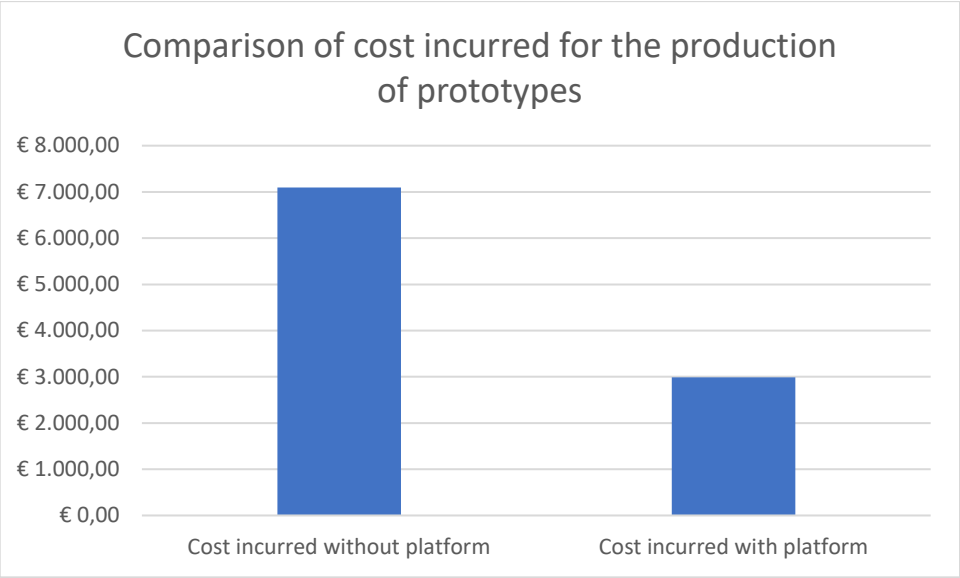


Figure 23 – *Cost incurred for the production of prototypes*

- Third scenario: if only the muslin will be done using the platform. It could happen, that only the toile will be produced because of the necessity to have the physical prototype required by the client. That's because the client wants to see how the garment could wear in reality. The material used (Fig. 24) will be lower, with a material saving of 37.35%.

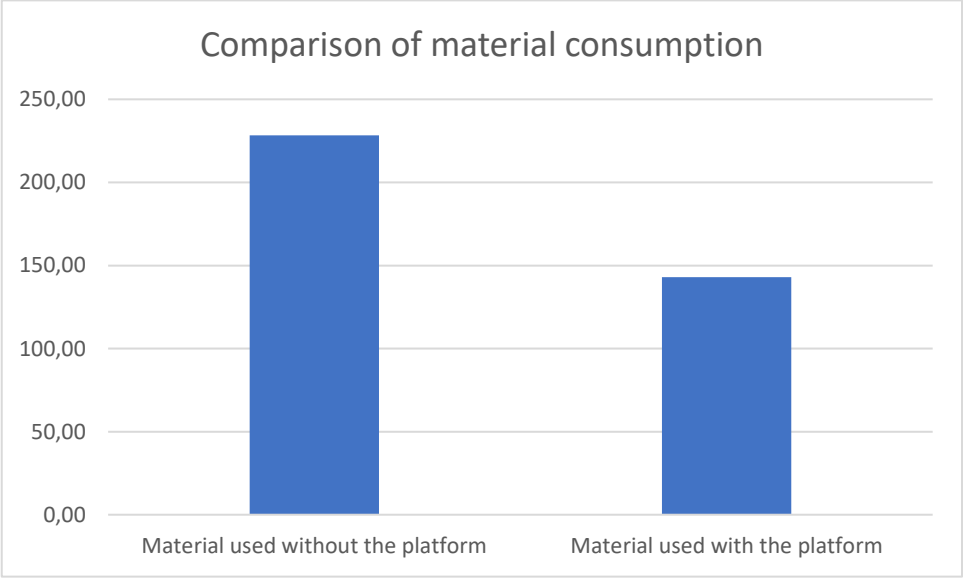


Figure 24 – *Comparison of material consumption*

The cost (Fig. 25) will be reduced with respect to the first scenario but will be lower with respect to the second scenario. The cost incurred using the platform could allow to a saving of 3.12%.

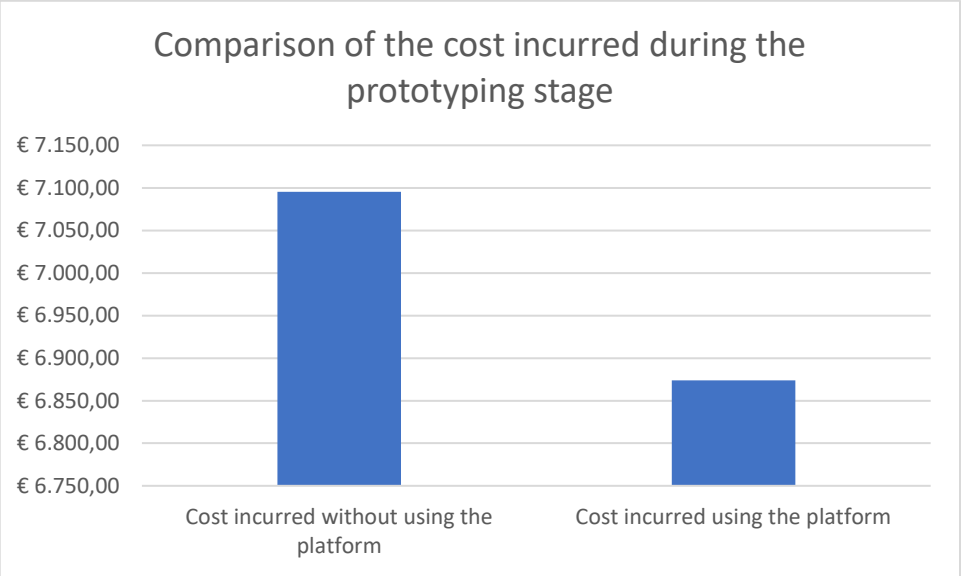


Figure 25 – *Comparison of the cost incurred in the prototyping stage*

3.5 Consideration and limits about the full 3D

This ideal platform has not only advantages, there are some criticism and limits that has to be analysed.

First of all, it has to be considered that the implementation of a system, and consequently the platform, requires a lot of time. Before to be finished in order to be sold, the software development has to follow six phases: requirement analysis, design, development, testing and maintenance [29]. During the requirement analysis the business requirement are analysed, and the output is a document where there are descripted several guidelines for the successive phases. In the design analysis, thanks to the requirement specification of the precedent phase, there is the specification of hardware and system, so the definition of the overall system architecture. In the implementation phase the work is divided in packages and the software development starts, the code is produced. When the code is finished, a phase of testing starts, and the software is analysed to understand if it fits the target requirement. Then, when the testing phase is finished, the software could be delivered to the customer for the beta test, in order to improve the software and then the final deployment happens. The last step is the maintenance, because when customers start to use the program, the problems come up and need to be solved, this task is made by the developer.

The implementation of the platform will require a lot of time, because the software development cycle has to be followed, and will not be in the foreseeable future on the market. Moreover, at the moment there aren't the resources and the technologies that permit to construct this type of platform.

It has to be taken into account also that this type of platform means that one of the main software houses want to enter into the market with one new product and it will revolutionise the actual paradigm of the apparel industry. The software house must be one of the bigger, in order to be followed by the other competitors, who also want to offer an innovative product to the market. This could be problematic, in fact the apparel industry is a sector that not quickly accept the new technologies, because of its artisanal nature. There could be, during the development of the platform, a problem in choosing the correct format for the 3D file. It must support certain geometries inside, because it has to cover a series of operative systems that follow different geometries. It has to encoded information for storage that could be adaptable for different software.

If developed the platform, it could necessitate a lot of time for the construction of the several databases inside of it. This requires a strong collaboration between the different actors of the value chain, an example is the database of textiles and accessorises. The supplier company that made the engineering part has to know the characteristics of the material used, and the textile or accessorise supplier has to insert the informations inside the proper database. The co-operation between the several actors of the value chain could be problematic, because everyone has to take into consideration their trade secrets. In fact, it has to take into account that maybe someone doesn't want to exchange sensitive information. The collaboration could be not only external, but also internal to company. The platform could not work well if the several actors inside the company will not work together and if a continuous exchange of information will not happen. At the moment, the main problem of the most apparel companies, is the lack of communication among the different departments.

Moreover, several software houses would to collaborate, in order to collect a large amount of measurement that have to be inserted inside the bodies database, with the intention of give the possibility to the customer to customize the mannequins. Although, the collaboration between the several software houses could be hard, because each one wants to offer a better product with respect to the product offered by their competitors.

Considerations about who will use the platform has to be made. People always tend to make the same process with the same passages, becoming there automatic. That's because the operators are subject to automatism and when a new procedure or a new software will be inserted inside their usual processes, it will not be immediately used, because it necessitates time to have familiarity with that. Furthermore, if the program or the new process is more or less simple to be understood, the people involved has to be trained. It's fundamental to create a parallel structure, where there is a group, who start to implement the new process with a portion of orders, following a type of garment and choosing the simpler model. That's because, at the beginning, it's important to start with uncomplicated models to better understand what the mechanisms of the program are and made it the routine process. These group would be drawn up on the classic method for the pattern creation and the fashion design, as well as on the use of this type of new technology. At the moment, the problem is that the technology method is not teach in the academy, so only when people start work have the first approach with it.

The platform gives the possibility to see immediately how the clothing at the end will be, without have the physical garment with a high graphic quality, but the apparel industry is an artisanal sector where it could be essential to touch and feel the textile.

The program gives the possibility to not produce the several physical garment, until it will be approved by the client. This will allow to a reduction of costs in material and production section, but it has to be taken into account that the implementation of a new program requires a huge investment, because of the need of a certain amount of licenses to launch the new process and transform the old paradigm.

It’s possible to conclude that this ideal platform, nowadays, could not be implemented for several reasons: technologic, human and costs incurred. In the next chapter, one possible alternative will be analysed, meanwhile the platform will be conceived.

4. Ecosystem for the integration of the 3D in the product development stage

As seen in the previous chapter, nowadays the technologies are not advanced in order to create a platform able to transform the actual process of the apparel industry. It's necessary to think about some alternatives, waiting for the necessary technology, in order to implement the platform described before. Taking as example the company Pattern SpA, the system environment inside it, and the solutions available of the software house used, it's possible to build an ecosystem able to use the 3D technology to implement virtual prototyping.

Pattern SpA has decided to collaborate with Politecnico di Torino and to invest into the virtual garment simulation. The technologies diffusion, in order to implement virtual simulation in the apparel realty, is still slow. Pattern SpA with its major clients commit themselves looking for a solution to incorporate these technologies in the actual product lifecycle.

It's important to know all the available functions of the technologies, in order to fully exploit their potential, but it's also important to pay attention on how the change could affect the employees. The change could not happen immediately, since the application of a new technology would significantly change the routines of the employees, changing the roles and the responsibility assigned.

Inside the company it's fundamental to create a parallel structure that implements several changes, in order to improve the actual product life cycle. The team of parallel structure has to be trained, in order to manage the change and to better understand the mechanisms of the new software. After the training, it could be possible to follow a simple garment of one traditional line at the beginning, in order to introduce the new methodology in the actual product lifecycle. With the aim of sustain the change, periodical check and a new company philosophy has to be developed, in order to better define the new 'instruments' and the new procedures.

In this chapter the useful software, available from the software house Lectra used by Pattern SpA will be analysed, in order to construct something that could be used to introduce the 3D technology waiting for the 3D platform.

Lectra is a technology company engaged in design, production and distribution of software and equipment to industrial user of soft material, as textile and leather. It was founded in

1973, and it's specialised in computer-aided design (CAD) and computer-aided manufacture (CAM) software and equipment.

Lectra is considered one of the leader provider of software and hardware for industry that uses the soft material, and it serves several market sectors: apparel, footwear, luggage, furniture, automotive and aerospace. At the beginning the company proposed PDM (product data management) solution, in order to create a technical file, so basic solution because at that time there were minimum requirements. Then, the company transformed its solution from PDM to PLM (product lifecycle management), that's because there was an evolution of the requirements and the needs increased: clients required major communication between them and their suppliers [30].

The software that will be descripted and analysed are Kaledo and Optiplan, in order to understand in which stages of lifecycle are used.

4.1Introduction of Kaledo

4.1.1 What is Kaledo

At the beginning the software used to represent the texture or the repeated image of the textile, were developed by Adobe, but the resolution of the images was not well defined. In order to satisfy the need to have a clear representation of textile on patterns, Lectra developed the software Kaledo, a graphic instrument. It has to be taken into account that the program by Adobe cannot be omitted, because of its diffusion, so the software house has found a manner to incorporate that into Kaledo, in order to have a connection between these two programs.

Kaledo could be divided in four modules: Kaledo style, Kaledo weave, Kaledo print and Kaledo knit [31] [32].

Kaledo style (Fig. 26) is able to transform the idea of the designer into drawings, reducing the necessary time to develop a new model. It has some features that permit to work taking weighted decision about the style, thanks to the availability of product specifications and colour palette. It's possible to work directly on PGS, in order to better understand the position of the textile on the model and also on the marker making software Marka.

Kaledo weave (Fig. 27) gives the possibility to simulate the woven textile with precision from both the visual and technical aspect, thanks to visual libraries of standard textile and customizable models. It has tools to acquire colours, yarns, weave pattern and surface design. It's possible to create stripes and plaid due to the function of mirroring and repeating sequences.

Kaledo print (Fig. 28) as tool for printed textile. There are some tools and brushes that help to control the number of colours used. It's possible to modify repeated images, duplication and dimension of images, respecting the colour constraints. It helps designers to better understand how clothing could be and if there are changes to be made.

Kaledo knit (Fig. 29) is able to treat the knitting, and by respecting some rules it's possible to insert figures. It has unlimited colours, textures and structures, in order to represent the original knit design. It also gives the possibility to simulate the textile on the garment thanks to the instruments that help designers to sketch stitches. It works very well with the 3D stitch simulator.

Figure 26 – *Example of drawing reported on Kaledo (Source: youtube.com)*

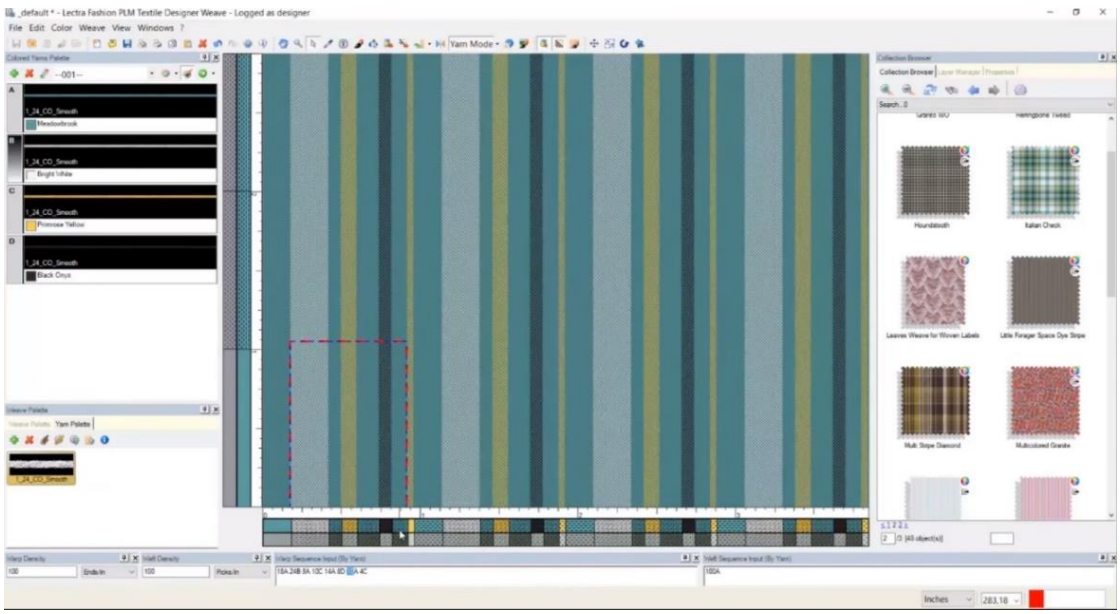


Figure 27 – *Example of waves textile on Kaledo (Source: youtube.com)*

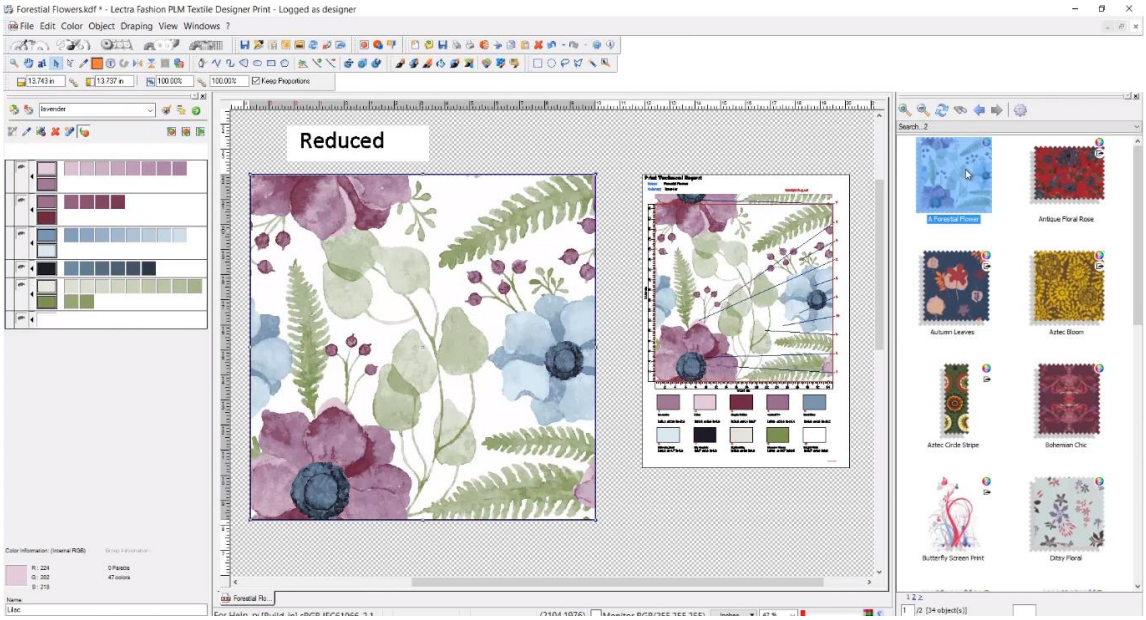


Figure 28 – *Example of printed textile on Kaledo (Source: youtube.com)*

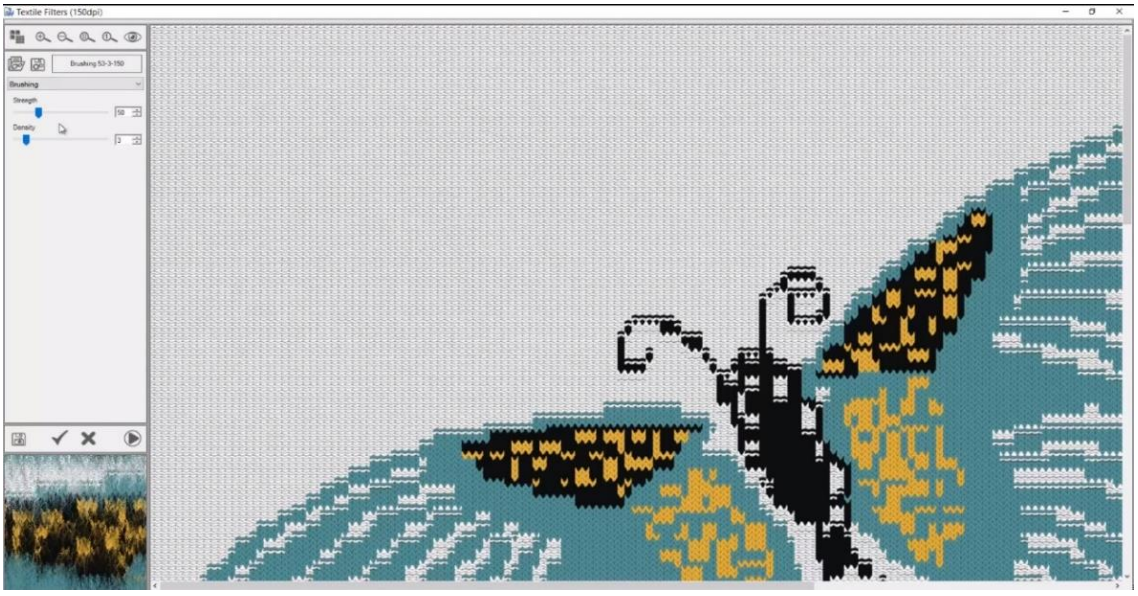


Figure 29 – *Example of knit textile on Kaledo (Source: youtube.com)*

These modules don't have to substitute the technical software, but they give the possibility with design instrument to work taking into consideration the fundamental elements of the drawings. Thanks to Kaledo it's possible to better understand the definition of figures on a particular type of fabric and to integrate the program with other software, like PGS Prototyping. It could be used with 3D software in order to take better decisions about the type of textile, that' because it is possible to create the texture of the fabric on Kaledo and then import the output on the virtual prototyping software. It's also possible to move the

textile represented on 2D pieces of the pattern, in order to have a visive impact on it. Kaledo gives the option to create drafting and to colour them, taking into consideration the company style. It also has a connection with the 2D, in fact if the garment is modified on Kaledo, it will be modified also the pattern, this work is possible on the software 2D, but not on the 3D. Using Kaledo, it's possible to import the geometries of the CAD software, in order to have more technical information, to understand how the several pieces of pattern should be assembled, to retrieve the markers of the garment and to modify the pattern in order to adapt the garment to the textile.

The software is also connected with PLM software, in order to have the detailed information about garment elements.

There are some advantages by using the Kaledo software: the program offers design instruments, in order to create colour palette, presentations and sketches, reducing the necessity of corrections, it's also possible to dedicate more time on design stage. This permits the reduction of time for approval, thanks to the clear visualization of what could be the garment [31] [32].

4.1.2 Where it could be placed

Taking into consideration all the functionalities of Kaledo and the stages of Pattern SpA, it's possible to use the program in several steps of the product lifecycle.

First of all, Kaledo could be useful during pattern making stage, when the pattern of the garment is created. That's because the textile could be reproduced on the pieces of the pattern, and it could be moved in order to comprehend how the final garment could be. The fabric could be plain, with single or repeated figures, embroidered, knitted or woven; depending on the design of the client; the representation of the textile during the creation of the pattern model could be helpful to better understand how to place it, having less misunderstandings between the client and the company.

Kaledo could be very useful during the pattern grading and marker making stage. During the pattern grading, the textile is represented on the several pattern pieces and it's possible to observe its behaviour with respect to different sizes. It's also possible to import the 2D pieces on Kaledo without modifying the geometries, the pattern grader could also adjust the patterns of garment, for example adding logo, writings or motif. An example could be a trench in which there are some writings, that must have determined position and size. At the moment in Pattern SpA, if the clothing requires a particular writing that changes size by size, the

pattern grader has to construct the writings, one character at time, and then they will be positioned on the garment. Every clothing size was developed individually, verifying if the writing was at the right place. This type of work could require a lot of time, approximately one week. Thanks to Kaledo, it would have been possible to do the same process easier.

At the moment, if there are particular textile during the marker making, with a print or a motive, the employee has to take a photo to the textile and upload it with Adobe, on the software Marka, and not always the photo is well defined. Kaledo gives the possibility to import the image of the textile in Marka, avoiding some passages, and positioning the pattern piece on the virtual textile, considering if the fabric has rules to be followed.

Kaledo could be also used in the Modaris 3D Fit, generating an image of the texture of fabric and having a complete vision of how the garment fits on the mannequin with that type of textile. It is possible to understand if the textile is good for that type of clothing and to measure the print yield. Using Kaledo with Modaris 3D Fit, the output generated will give a realistic view of what could be the final product (Fig. 30).

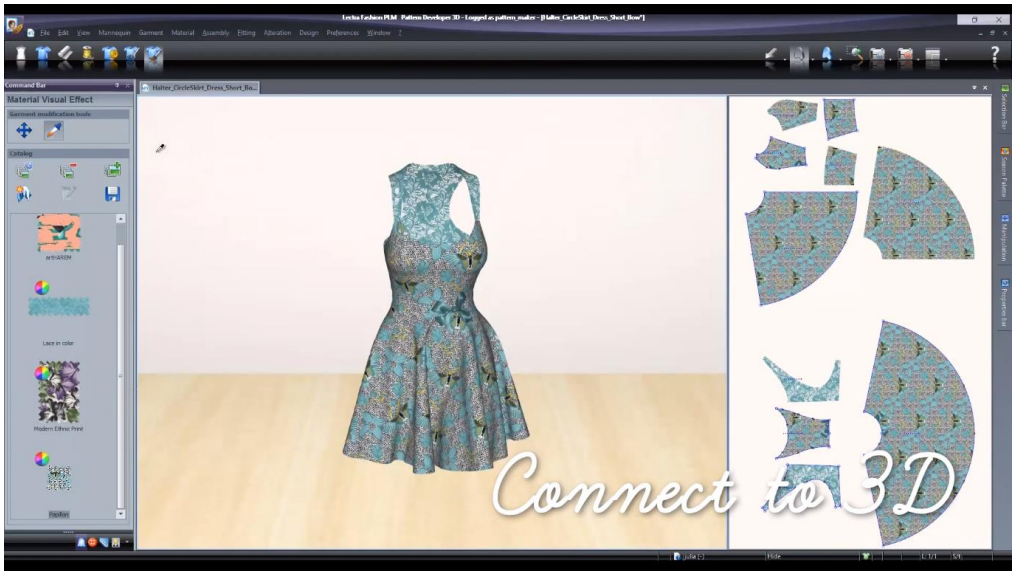


Figure 30 – *Example of connection between Kaledo and PGS 3D (Source: youtube.com)*

4.2 Introduction of Optiplan

4.2.1 What is Optiplan

The fashion market is constantly changing and there is the necessity to have a fast and flexible production to handle the succession of order, maintaining profit margins.

The program Optiplan is a lean production software, able to transform complex orders into a series of simple optimized instruction. The software is designed with a specific characteristics required by the apparel manufacturing. It applies manufacturing principle to cut operation, in order to create an efficient cutting room. That's because the textile is the largest factor considering the garment cost, and optimizing the cutting room, there could be a reduction of waste of textile [33]. Optiplan permits to create a data integration between CAD with the cutting room and the management system (Fig. 31). It could inherit information and match them, in order to solve the committees giving the right marker with respect to optimization parameters.

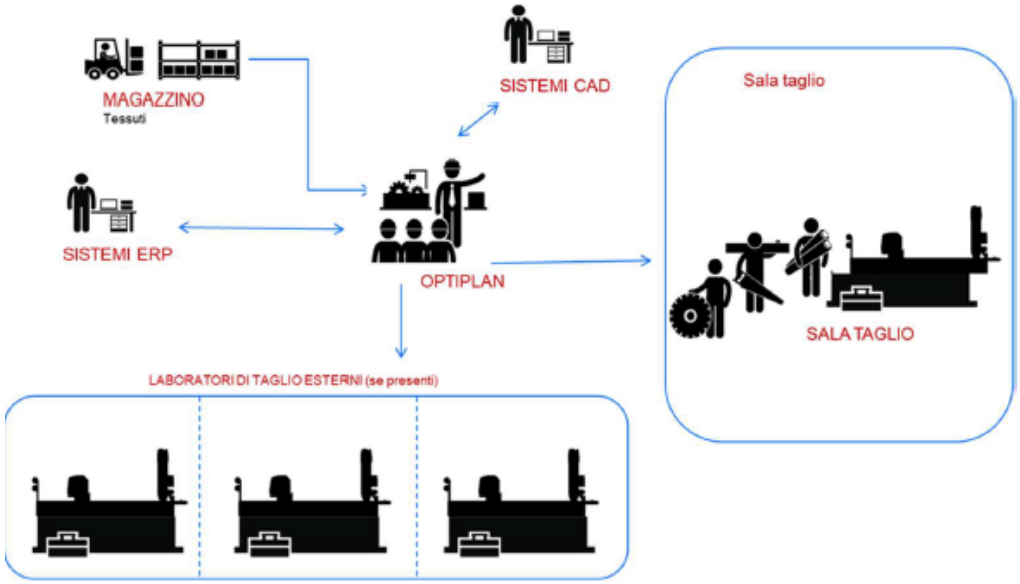


Figure 31 – *Interconnection created by Optiplan (Source: Lectra.it)*

It could find an efficient and convenient way to reduce the textile consumption and the stocks. The software allows to a better communication between the several department inside the company, making the processes more integrated, from the order placement to the warehouse and from the CAD systems to the cutting room.

It's possible to simulate with Optiplan all the possible scenario for the production, in order to take better decisions and to reduce the errors, allowing to a better strategic decisions.

The software permits to forecast time and costs necessary to the production of a garment, taking into consideration the labour cost, the employees and the cost of machines (Fig. 32).

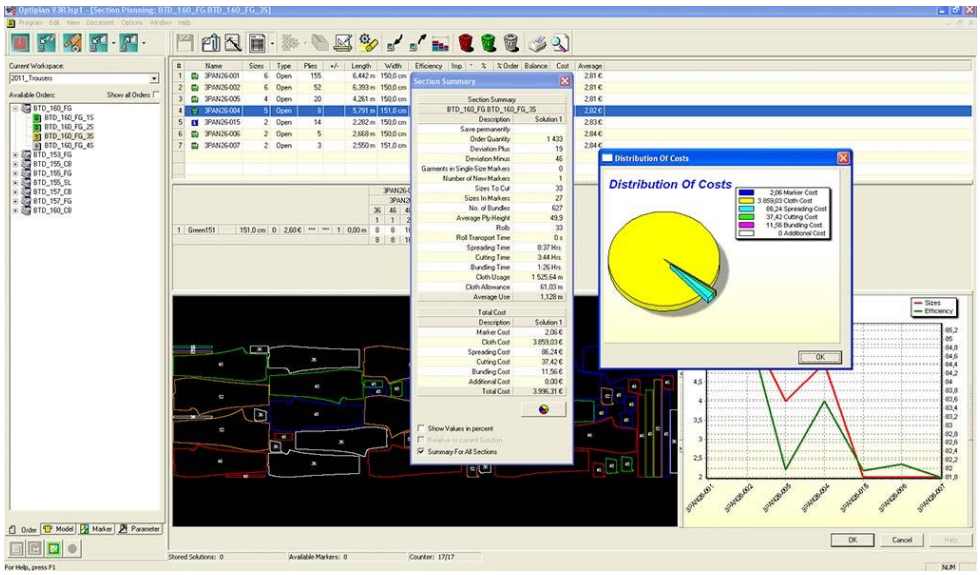


Figure 32 – *Example of planning cost for a garment (Source: ocs-po.sk)*

It permits to make comparison between the heights of textiles (Fig. 34), and it makes simulation of the possible models, sizes and marker combinations (Fig. 33), with the intention of make the order of optimal textile. The software allows to reduce the surplus and the lack of material in the warehouse and to satisfy the order in time, as well as to have an evaluation of cost and productivity level. It's possible to see the stock of material for an order and the consumption for the material needed to prepare a garment, avoiding extra production and purchase.

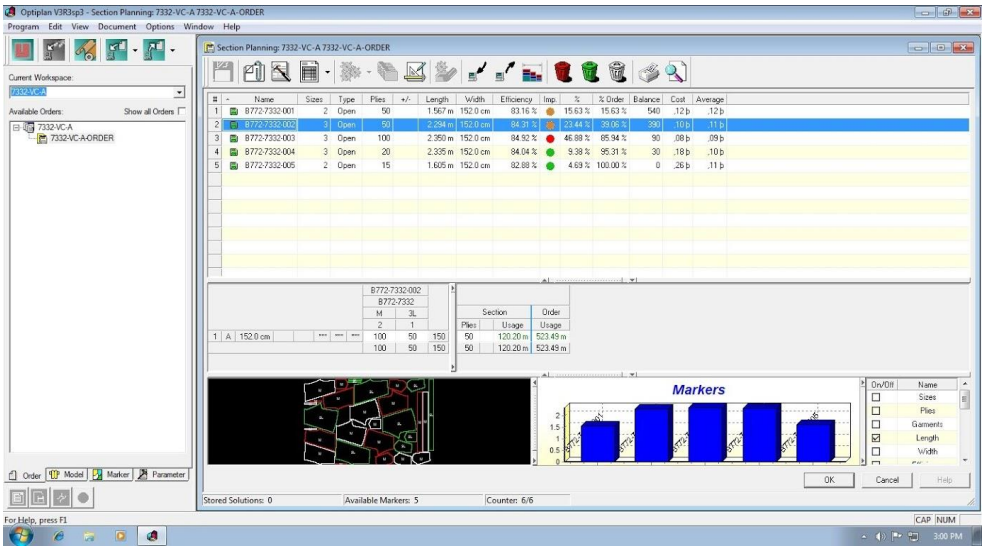


Figure 33 – *Example of marker simulation with Optiplan (Source: congnghemay.info/)*

Taking into consideration the fast changes in the apparel industry, Optiplan could program and adapt the production activity and to reschedule the production plan because of a change with respect to the priority of orders. It considers all the characteristics of the several cutting rooms and depending by the type of garment, redirect the order towards the best choice of cutting room to satisfy the order [31] [33].

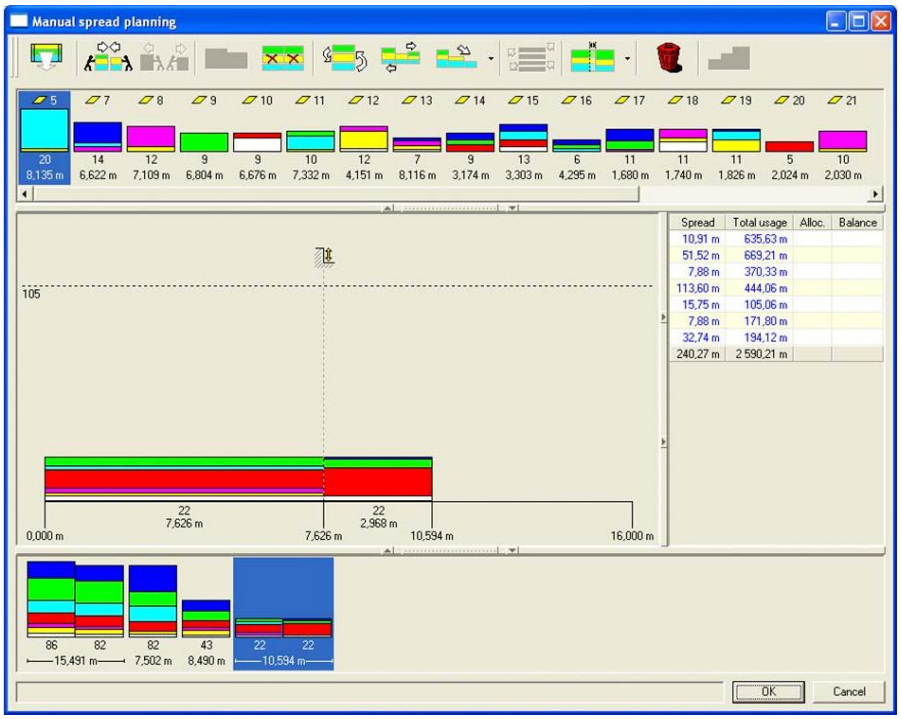


Figure 34 – *Example of comparison between textiles (Source: ocs-po.sk)*

4.2.2 Where it could be placed

Optiplan could be, inside Pattern SpA, a useful instrument to organize the several cutting rooms and to have a guide line about what could be the future orders of material.

The software has double advantages: it could be used during the sample stage to facilitate the standard models and during the production stage. When the model is in sample size, inserting some information about the number of pieces of pattern, the subdivision of them with respect to the type of material used, the sample marker and inserting some parameters about the grading, it is able to calculate a dummy order, a dummy grading and a dummy marker for each size. The software could also import the information about the textile used, hence calculate a mock consumption and a prevision of what could be the next order for that textile, but it will not be accurate as planned order of material with the MRP, obviously because the las one considers several elements, as the lead time, the actual stock and if other

orders are already placed, calculating the effective quantity to be ordered. So Optiplan could be an useful instrument to make forecasting, unwilling to substitute the MRP.

During the production stage the software will take in consideration all the information about the clothing, as described before, but has also the real orders and the real grading for each size and the type of textile used. The software will generate a cutting cards for each scenario developed, within information about the number of pieces to produce for each size and material. For each material will be indicated the best option of marker. All the marker will be checked at the end by an operator to evaluate if the marker could be used during the cutting stage or it has to be modified.

It could be possible that sometimes the material could be affected by some changes, like the height of the textile. Inserting the information about that changes, it's possible to relaunch the program and it will recalculate the markers for each size taking into consideration the adjustments and also the orders done, and it will report if there is the need to make another order. At the moment if there are changes about the textile height, the construction of the new markers for each size with the new height is done manually, and it requires a lot of time. The software will save time, resources and it's possible to reduce the possibility to make errors because at the moment, the information about changes are received meanwhile the operators are doing other requests.

The consumption of material calculated by the software Optiplan is more accurate than the calculation done internally, that's because the manual calculation takes into consideration the consumption of the marker of the sample size, and then to calculate it for the other sizes, it's added a percentage to the sample size marker consumption. Optiplan make another calculation, it takes into consideration the height of the textile and it increments the area of the several pieces of the patterns about a certain percentage, changing the position on the marker, to calculate the consumption. The software is able to store the past marker and the past percentage, in order to have more accurate future marker.

The company Pattern SpA has more than one laboratory to satisfy all the orders, with Optiplan is possible to register several profiles that distinguish the different laboratories and it's possible to understand in which laboratory is better to send the order taking into consideration the existing machines in each one and the several orders. That's allowed to a reorganization and optimization of the cutting rooms.

4.3 Introduction of 3D

The actual CAD system is not able to provide virtual simulation tools, in fact it is based only on geometrical modelling, that's because the system is conceived only for design purpose. The prototyping and the design phases are done manually and so the process requires time and costs. At the moment, the clothing has to be produced several times, in order to make the modifications decided during the fitting. All that steps required are expensive and require a lot of time. Nowadays with the growth of the demand, the necessity of a virtual garment development is needed, in order to optimize the apparel industry product lifecycle [34].

At the beginning the 3D technology was used only to understand the style of the clothing. Nowadays, with the improvement of technologies, a software 3D could be a tool to reduce the product lifecycle, in order to reduce time-to-market. This type of technology is largely used as powerful tool in many other industries, like aerospace, architecture and industrial design [35]. The use of 3D technology in the product lifecycle of apparel sector could be an advantage, in fact that program could be seen as a progressive method of rapid prototyping. The 3D software would be able to visualise virtually a clothing and experiment several type of fabric, before it will be manufactured, allowing to a better communication between the several actors of the value chain [36]. The virtual prototyping allows to a reduction of lead lime, lower number of physical prototype and to reduction of errors when integrated with 2D and the PLM software [34]. It allows to spend less energy to produce the prototypes, much higher quality earlier-on in the cycle and to a reduction of waste. The virtual prototyping could also let to respond quickly to the clients, to reduce cost due to the multiple iteration of sample, to take faster decisions and to give the main shape information. The virtual garment could be useful for online retailer, in order to reduce perceived risk regarding the apparel fit and also for marketing purpose, as aid for online product presentation and internet-based retailing. There are several software for the 3D virtual simulation such as *Modaris 3D Fit, Vstitcher™, 3D Suite* and *Clo3D*. That software are able to convert the 2D patterns in a finished virtual garment on virtual mannequin [37]. At the moment it is possible to divide the software into two categories: in the first category there are software that have been developed with the aim of being mainly support for production, while others favour the graphic aspect, useful for marketing and retailing purpose.

Inside Pattern SpA is installed the software Modaris 3D Fit, that belongs to the first category and it is one of the first three-dimensional software to be developed. The program needs the support of a 2D CAD, PGS in Pattern SpA, where sewing operations are done (Fig. 35). The

representation of the 3D mannequin wearing the clothing required several steps on 2D CAD software and then the pieces of the pattern will be constructed on the 3D dummy body. In the software is possible to see both the 3D garment and the pieces of which is composed (Fig. 36).

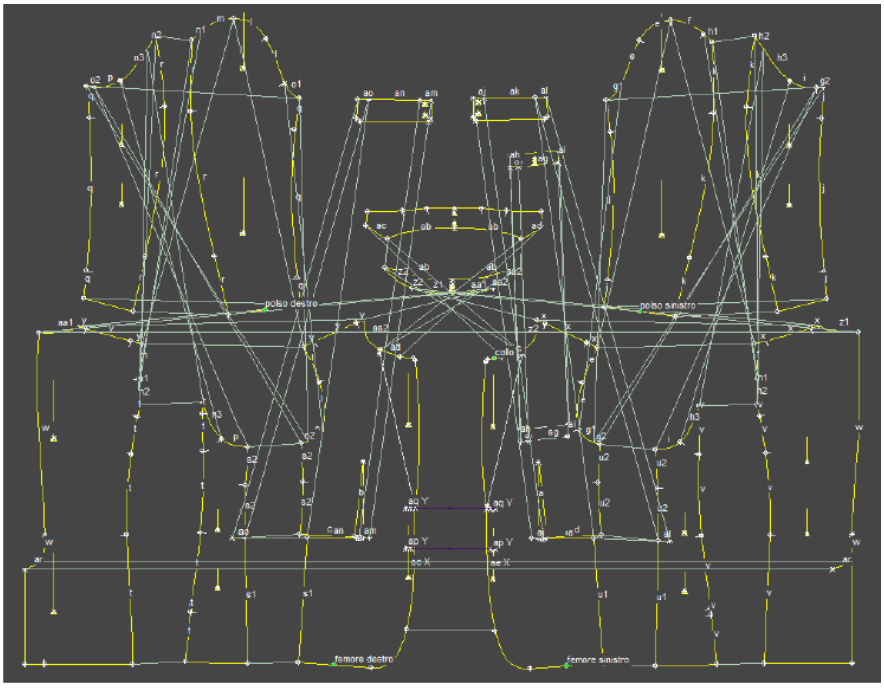


Figure 35 – *Pattern's pieces linked to be constructed on the 3D mannequin*

Figure 36 – *Example of the screen of software Modaris (Source: it.fashionnetwork.com)*

The program has several feature, as the customization of the mannequins with respect to defined parameter (Fig. 37), several posture that could take the dummy body and the choice

of textile. The last one is very important, so that it's possible to evaluate how the fabric will drape on the body. It's possible to use several type of textile on the same clothing and modify the characteristics of textile.

Figure 37 – *Example of customized mannequins*

The simulation is made automatically by the software and when the dummy body is dressed (Fig. 38), it's possible to make changes on the garment and they will be visualised both on the 3D model and on two-dimensional section, but on the 2D patterns is only signed a mark, the changes are not made automatically by the software. It's possible to add accessorises, however they will treat only as images. In order to check the fit of the clothing, the different pieces of garment will be differentiated using several colours, in order to understand which are the parts subject to high deformation and with low deformation. At the moment the company is not using the software, that's because there is not a proper structure that is focus only on the use of that and its usage will increase the time required for the production of garment [31].

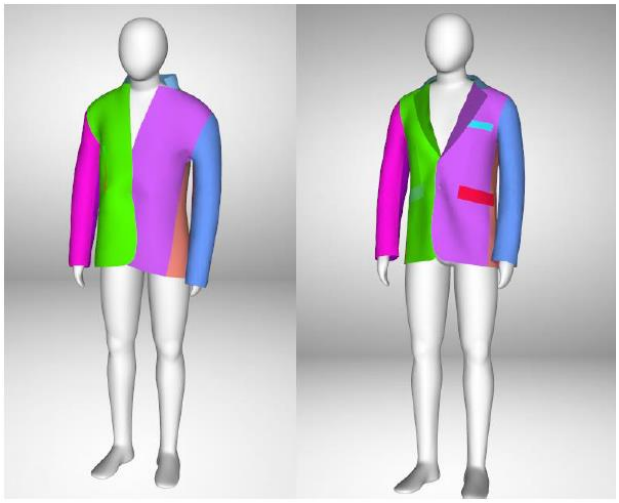


Figure 38 – *Dummy body dressed*

The actual software has some criticisms that have to consider. First of all the difficult usability, in fact the software, as written before, needed the support of the 2D software and it requires knowledge of how the pieces are linked. In order to insert the virtual prototyping in the product lifecycle, a training from external consultant is necessary because Lectra has not free material for the self-learning, in order to understand the features and how to use it. It's necessary to construct a parallel structure that will start with a simple and standard garment, with the aim of make practice with the features of the program and then do more complex clothing, increasing over time the number of garment with rapid prototyping.

Another criticism is that the accessorises are treated as images, so they are flat, allowing the user to not have a realistic image of how the accessorise could be on garment, due to the low-quality image. The software has a database of limited number of textile and it is not giving a proper simulation of the virtual fabric and its texture. The visualisation of the textile is complex and not clear, that's because the materials are anisotropic, they differ from area to area and the process of translating the physical and chemical data into 3D simulation is problematic due to the varying and unpredictable nature of cloth. It's important to understand the relationship between the individual threads of the fabric and that the clothing will drape differently, depending on how the garment is cut [38]. In the actual database of textiles, there are only few physical properties measured and there is the necessity to make several specific tests, in order to substitute the default set-up of the fabrics, and also to enlarge the actual library, making it more detailed and customized, considering the several materials used and their physical and chemical characteristics related to the feel, drape and reaction on the body. This improvement could allow to a more realistic visualisation of the fabric on the dummy body.

Additional issue is due to the virtual mannequins: each time there is the necessity to create a virtual model, an avatar with the most similar measurements to the performer would be selected among several mannequins with different body shapes available in the software. The catalogue of bodies actually available in Modaris 3D Fit is characterized by few defined parameters that described the measurements of dummy bodies. In order to develop accurate models some modifications have to be done in the actual database. It's necessary to enlarge the parameters of the mannequins, trying to collect more data and have necessary measurements to appropriately adjust standard manikins in the software and to make them more customizable taking into consideration the requests of the client [38]. Consequently the software would provide more accurate mannequins for virtual prototyping. The storage

of more realistic measurement could allow also to a more precise pattern making of a clothing.

It's possible that the fitting of virtual garment could change with respect to the posture of the dummy body. The differences could have implication on the accuracy of virtual fitting, that's because some posture may result not in-contact with the body. The changes, that could be done, are about the movement of the dummy body in order to be more bendy, and it could be possible see how the clothing changes with respect to the movement of the mannequin [38].

During my permanence in Pattern SpA, I participate at the drafting of a project that has the objective to redefine the actual paradigm of the company using the Model Based Design approach. One of the innovation that the project is intended to reach is the implementation of the new paradigm that is able to focus the productive process on the virtual prototype. This will be possible thanks to the introduction of another 3D software, after a detailed analysis of available technologies of the second category before described, developing a multi-CAD area. The software could be able to emulate the texture of the fabric on the mannequin, to the simulate the real garment movement, giving a high-quality 3D clothing [39]. The program will be used in order to increment the visual rendering in two application areas: the former as support in the decision-making process during the collection planning and the latter as support for marketing and retailing activities. The software already available in the company, Modaris 3D Fit, will be used during the prototyping phase. Another innovation is about the digitalization of the physical and chemical characteristics of fabric used. The data will be stored into a database developed during the project, and it could be used by all the actors of the value chain, allowing to a better communication among all the actors of the value chain, an example is the laboratory that will cut the fabric. The fabrics database will be created by the fabric supplier. They will define the parameters that better describe the behaviour of the textile and subsequently they will also do the tests to put a value of parameters. This database will be integrated in the two software 3D that the company will use. The innovation of this new paradigm could improve the pre-industrialization phase, because there will be possible to simulate how the garment in sample size fit and made modifications directly on it, before the creation of the physical prototype.

These series of improvement could impact largely the company. The size, shape and posture are important to the success of virtual fitting, and with the improvement of the fabric

database, it could increase the confidence in the accuracy of the virtual garment and more companies will use it, in order to change their product life cycle.

5. Conclusion

In this work it is performed an analysis of technologies available in the apparel industry and which type of upgrade could be done, in order to follow the principle of the industry 4.0, allowing to an improvement of the actual product lifecycle. To do so, it is made an analysis of the actual state of apparel industry, of the main principle of Industry 4.0 and how that principles could be applied in the apparel sector, generating the fashion 4.0.

After it was made an analysis of the information system actually installed in Patter SpA, in the product development process and the criticism of the process are: a large amount of data created that are not well managed among the supply chain, difficult communication between the several actors of the value chain and the presence of more than one physical sample, because of the need to satisfy the request of client. These are due to a short product lifecycle, an uncertain demand and a continuous customer's requests, allowing to an increasing risk of errors and a reduction of product quality.

Taking into consideration the maturity level of the other sectors and how the 3D software is totally integrated in their product lifecycle, a platform that full exploit the 3D technology in the apparel sector is studied, explaining the features that it could have. The full 3D platform could be a support for the several stages of product development process, reducing the lifecycle time, the material consumption, waste and the costs of production. The technology available today in the apparel sector are not at the same maturity level of the others, so in order to introduce the 3D technology in the actual product lifecycle an alternative has to be studied.

In order to have an improvement of the product lifecycle in the fashion industry there is the need of digitalization of data processes and of supply. An analysis of the 3D software actually installed in the company and its principal features is made and some criticisms are found: the need of knowledge about how the pieces of pattern are linked, there are limited customizable parameters of body measurements, the accessories are treated as images and there are not well defined, and the textile are defined with restricted number of parameters that characterised the behaviour of fabric. Also an analysis about the instruments that could also accelerate this process is made: Kaledo and Optiplan. The first one is a graphic software able to create texture of fabric and it could support both the software 2D and the 3D actually installed in the company. The second one is Optiplan, a software for the optimization of the

cutting room and matching it with the 3D software it's possible to reduce the consumption of material and the waste.

On the basis of 3D software and the product lifecycle criticism, the company Pattern SpA in collaboration with Politecnico di Torino, has structured a project where the goal is the development of new paradigm based on Model Based Design approach, in order to introduce the virtual prototyping stage in the actual one. The project has the intention to introduce different type of 3D software, one developed with the purpose of being principally support for production and the other one favour the graphic aspect, that could be used for marketing and retailing purpose, in order to develop a multi-CAD area. A study of which could be the standard format to exchange informations is done. During the project, thanks to the collaboration of Pattern SpA suppliers, a database of textile used will be developed.

If the project will be successful, the apparel sector will have a direction to take, in order to have profound change in the actual product lifecycle to reach the same technological level that the other industries have reached, introducing the virtual simulation in their processes. Considering the criticisms that characterize the sector, this change of paradigm with the insertion of the 3D technologies is necessary, otherwise the fashion industry could be underdeveloped in future, due to the increasing demand, and it could fail to deal with its critiques.

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