POLITECNICO DI TORINO

CORSO DI LAUREA MAGISTRALE IN ENGINEERING AND MANAGEMENT

TESI DI LAUREA MAGISTRALE

Product Lifecycle Management in fashion industry :
evaluation of the impact of PLM tools in a specific enterprise

Relatori: Enrico Vezzetti,
Marco Alemanni

Candidato: Licia Pagano

Tutor aziendale: Laura del Noce

ANNO ACCADEMICO 2019/2020

ABSTRACT

Product Lifecycle Management (PLM) is an increasingly important requirement for organisations acting in dynamic and competitive markets. In practice however, PLM is rather a concept than a system and for this reason its implementation is not simple but requires integration between different systems and structural, cross-functional and long-term cooperation between actors in and outside the firm. In recent years, PLM has been introduced in several industries, including the fashion industry, in order to manage the new product introduction into the market and its development cycles and be able to deliver the product on time. The central aim of this paper is to define a PLM framework, describing its features and applications, and to analyze a specific case of a company which adopted the PLM approach, providing an assessment of the current scenario and giving some insights to improve PLM implementation.

Contents

INTRODUCTION

Product Lifecycle Management (PLM) represents a strategic approach for the management of a product during its lifecycle, from the first stage of design, planning, development, until the final stage of production and introduction in the market. In recent years, it is becoming more and more complicated to manage the lifecycle since all the activities performed along the value chain must be coordinated and efficiently managed in order to gain revenues and reduce redundancies. For realizing such coordination, product engineering and manufacturing are becoming strictly integrated processes, enabling the communication between all methods and environments dispersed along the process.

In today's challenging market, the success of a new product introduction is determined by three main factors: the reduction of product development time, the increase of product innovation and, finally, the re-use of company's knowledge and resources. To reach this level, a company must have full control over its process, and this means having the ability to manage resources and activities and bring significant value to its customers, stakeholders and organization.

The aim of this work is to analyze the Product Lifecycle Management, particularly in the fashion industry and apparel manufacturing fields, and to contribute to the area of PLM implementation through an in-depth study of a real case.

The work is structured as follow: (1) the analysis of the literature has made it possible to define the PLM, its origin, main advantages, functionalities and market requirements for the fashion industry, (2) the analysis of the case study of an Italian company, Pattern S.p.A., operating in luxury fashion engineering which has adopted a PLM strategy, with detailed description of its process, main activities, resources and used tools, (3) the analysis of the ICT market and software solutions, with general and specific functionalities for the fashion sector, starting from preliminary requirements for the introduction of a new software until its implementation, and lastly (4) the description of the change management and the definition of a PLM assessment method, with the focus on the approach adopted by the company and through an empirical assessment of the state-of-the-art.

Chapter 1

1. Introduction of PLM in textile industry

Product lifecycle management (PLM) is a strategic approach for the development of a product in all the stages of its lifecycle, from the design, planning, production to the final stage of marketing and commercialization to the final customer. It represents a system for data management of an enterprise or of a single project and, through the integration of tools, it makes data available to all interested parties. In fact, the PLM is based on a shared access to a common source from which it is possible to extract product data, information and processes. Its use is widely common and well established in the aerospace and automotive sector, in which it is essential to follow step by step all the stages of a new product development (NPD), being the latter focused on research and development (R&D). [1] In fact, the concept was firstly introduced in these sectors, due to needs to manage complex projects in which a product is characterized by billions of parts and where it is extremely difficult to keep track the entire process without the help of a system that unifies production stages.

It is essential to understand how this tool can support processes that take place within a project and subsequently it can be applied in a specific sector. For example, the textile industry is still very traditional, but it needs to revolutionize itself in order to continue to survive in an era strictly focused on technological progress and innovation. The society is constantly changing its standards; the market requires a specific production, high quality and all in a shortest time. For this reason, companies are required to be more flexible to meet demand and to survive in the industry. According to a survey done by The Business of Fashion in collaboration with McKinsey & Company, the word used to describe the industry and that comes to the minds of most executives was “changing” (34%). The second and third most common words are “digital” and “fast”. The implication is that change has become a key priority among industry leaders, with a particular focus on digital and speed-to-market. [2]

Even the more traditional sectors have introduced elements of innovation and new technologies; human labour is no longer sufficient to carry out the activities but has be integrated with the artificial one. In the textile industry, many labour activities still prevail, such as design sketch, tailoring, 2D design and physical prototyping samples. However, to ensure the development of

the sector, it is necessary to integrate these activities with the right means to facilitate human work and improve performances, promoting the growth.

1.1 Origin of PLM

PLM has its origin from PDM (Product Data Management) from which it takes the fundamental principles and it constitutes an attempt of evolution towards a new technology. PDM was the first approach that dealt with management system of product data and information. In particular, it regards the management of the technical documentation like CAD, CAM or CAE and project documentation, such as material-related files. Due to increasing market pressures, it is not sufficient to meet the technical requirements but many others must be met and so, in the last years, PDM is evolving in PLM with new functionalities that take into account different variables and not only data strictly connected to the product. These changes derive from the needs to reduce more and more the time to develop a product and, as a consequence, the need to accelerate time to introduce a product on the market. Furthermore, in the last years more advanced tools have been adopted for product development, such as CAD, CAM, CIM, MRP, and being independent solutions, they require to be integrated with other informative systems. Another determining factor was also the increasing volume of data that is produced by a system and the application of different software at each organization level. Also the definition of data has changed and now includes any relevant information for the enterprise and for its stakeholders, whatever is a technical information or an information concerning a person. The impossibility to define a system where the information are of the same type and the multiple existing applications have lead in defining the PLM as a more flexible system and less focused on specific problems like PDM. The adoption of PLM has three main advantages:

- It improves the quality of data and, even if data is of different types, they can be associated to the same product.
- It offers greater consistency of data, in fact, data become effective immediately after being created or updated. This avoid the risk for employees of working on different versions of the same file and consequently of updating manually the documentation.
- It brings data transparency because the whole project or product is simultaneously analysed by different working groups or departments without waiting for the final version. People can work on the project even if the previous stages is not yet completed, a feature typical of a concurrent engineering approach.

- It introduces information control and distribution, by giving the possibility to deliver the right information to the right person at the right time on the right tool and by setting authorization to modify data.

Since the amount of produced data is growing exponentially, the biggest challenge for companies is to manage documentation. PLM systems intervene on the whole process, eliminating bottlenecks and increasing productivity. These solutions can bring concrete benefits only if they use the entire infrastructure for product management under a global strategy. If they are used as independent modules, they will not introduce any additional benefit and, on the contrary, they could bring to disruption and disintegration.

PLM solutions give the best of themselves when support all systems involved in the development cycle, from preliminary design, to modelling, to production, to management updates, to delay the obsolescence of product until its final disposal. They are used mostly in technical areas but should be used also in commercial areas, marketing, product quality and others because directly involved in the definition of product specifications. The introduction of a tool that is used in different areas of an organization represents the real evolution.

1.2 PLM in fashion industry

It is important to understand how the PLM could help the companies involved in fashion industry, and particularly in textile industry, and why they should apply it. When deal with new products development, it is essential to have all the information about the product itself, the environment, the actors who participate in the processes and the information on ongoing activities. All the information should be available to the correct people and the right time. This is because the fashion industry is changing at an incredible high rate and here we find the concept of "fast fashion". The market demands more flexibility and a quick response to customers' needs. On one side, there are macro factors that affect the textile sector, such as economic and geo-political factors, fluctuations in the cost of raw materials, exchange rates, new policies regulations and sustainability requirements. On the other side, technology changes require companies to self-adapt, by adopting new methods and innovative technologies and by substituting those tools that have already reached their maturity. The introduction of the innovation and of new means can help in dealing with the product complexity and the

difficulties related to the production, with the geographical and cultural differences in the network, with the uncertainty of the customers' behaviour and particular events that constitute the main challenges of fashion industry.

1.2.1 The product lifecycle

In the last years, companies in the textile sector have started using PLM-oriented tools. The first use of PLM, or PDM (Product Data Management) as it was once called, was in the aviation and automotive manufacturing industries. In fact, it was in these fields that the development of new products first necessitated a tool to manage the collaboration of its many resources, due to the difficulty of manufacturing a product without an established set of processes for each stage of the production and the difficulty to manage product complexity. Product lifecycle management is born to represent the process of managing complex product information, engineering and manufacturing workflows, and collaboration. PLM goal is connecting people, processes and data across the entire product lifecycle within a central repository of information. PLM is no longer limited to the aviation or automotive industries but, in recent years, it was introduced in other industries, such as apparel and fashion, and its use is now consolidated. The reason for the PLM adoption in these sectors is not mainly for managing the product complexity but because its need in increasing the speed in product introduction to the market, joined with low-cost and quality requirements.

Each product has its own life cycle and follows different stages before being merchandized. Here, product lifecycle is meant as a sequence of stages in the product life, not in the market. We can identify four broad phases in the life cycle, common to everyone:

- Each product is born from a concept or an idea. In this phase, much research is done to define the product in order to understand the technical requirements, the feasibility, the attractiveness and expectation from customers' point of view and the product profitability. In fashion industry, from the perspective of a fashion company, the *conception phase* of a new article of clothing includes searching for ideas among fashion trends and cataloguing various pieces of inspiration. A good PLM system should be able to allow designers to easily track the evolution of a new product and to introduce some analytics, even at this early stage of the product lifecycle.

- The second phase regards the *design*. Once the initial idea for a product is established, it can be designed and prototyped. Here, designers work to transform the concept of the product into something physical. It comprises of creating mock-ups, prototypes and finally testing. For example, the design cycle of a garment consists of drawing, sample production and lastly fitting. PLM solutions need to include integrations to third-party vendors to streamline the design process. This way, multiple actors can work directly on the platform and documentations while being seamlessly connected to the PLM, avoiding file duplication and speeding the work. Furthermore, PLM software coordinates those involved in the development of the product with built-in project management tools, sharing the most updated information to them.

- Using the data from the previous stage, the product enters the *manufacturing phase* of the product lifecycle. The final design is shipped off to the production environment where a different set of KPI's must be monitored. Usually, this phase is managed with an ERP system that accounts for materials, costs, components, productivity, timeline and supports all business processes and operations including manufacturing, marketing, financial, human resources, and so on. It is paramount that a PLM system is integrated with an ERP system and that it can account for each of the variables at play during production, otherwise it will face unexpected costs, delays and inaccurate forecasts.

- The last phase of the product lifecycle includes the *distribution and maintenance* of the final product. A firm needs to manage the warehousing of the final products and the distribution to its various sales channels, and at the same time, it should monitor sales and customers' data to assess its overall performance. By storing data about past performances, it can use them for evaluation and impact on new projects. A PLM software is typically used to keep track of that information as the product enters into the market. This allows an apparel company to manage the retailers, distributors and marketplaces it distributes to, while gaining data on whether that particular garment has been successful in the market and can be replicated or has to be disposed.

1.2.2 PLM functionalities

PLM enables a company to go deep its business and understand the mechanisms that regulate its activities. By acquiring knowledge and expertise, the company is able to reorganize its structure, define the processes, distribute and optimize its resources and achieve efficient performances.

The main functions that a product lifecycle management solution offers are described below:

- Take the control. The use of the software allows the company to have control over all the stages of the process, from design of the product, to production and distribution to the end-user. For instance, it will be able to know where the products are, the working progress, the stock units and so make a planning of the next steps. A brand company needs to put on the shelves its products as soon as possible and has to follow the speed of fashion trends. This requires knowledge of the style and the ability to make market forecasting. Having control over the assets and of its own business means managing uncertainty and being competitive in the market.

- Communicate. Nowadays, companies in fashion industries are more and more vertical disintegrated. A firm could carry out only a specific task in the big scenario of the supply chain, so it is required a strong communication with the other actors in order to share information. In addition, given the increasing complexity of the product, it is necessary to rely on third parties for the procurement of raw materials, the creation of the product and the management of resources. In general, the big fashion houses take care of the design and the style, developing the collections and then, they turn to third parties for the planning and production of the whole collection. The latter constitute a network of suppliers who take care of the manufacturing processes, like the procuring of raw materials, the definition of the parameters of the garments and the final realization of them. Third party providers generally manage the distribution of the final products and logistics.

- Collaborate. As outlined above, many actors are involved in the supply chain and they constantly share information, otherwise it would not be possible to carry out the activities. People inside a firm should collaborate to respect scheduled deadlines and milestones and achieve business goals. An enterprise is divided into many departments; each one gives its contribution and has a specific role. There are many tools that help improving the teams' collaboration by reducing the time to get information and simplifying the access to the data.

Externally, there must also be collaboration between different companies through the sharing, communication of changes and possible actions to take in the event of unforeseen events.

- Take responsibility. The PLM tools define specific areas and outline the different processes that take place within a working environment. Employees of a department will use specific functionalities of the software, so having visibility helps everyone involved in the product lifecycle to understand their role and the impact of their actions on the success of that product and, ultimately, on the brand strategy. Each employee in a company, at a low-level position or in upper management, works daily on a specific job and is responsible of his actions.

- Improving. The introduction of a PLM tool inside an organization is certainly a great change. Daily activities are redefined according to the instrument. The workflow is mapped by the system and employees can derive information about the status of the activities, those already performed and those to start. Information are accessible to everyone and they can be found at any time, cutting down on time spent arranging the pieces together. At last, the tool helps companies standardize and reuse existing processes and resources but with a significant improvement in performance.

1.2.3 PLM advantages

In the last paragraph, the main functions of PLM have been described to clarify what exactly it allows to do. Now, we analyse the advantages that the system brings to an organization.

Time is a critical success factor for a company. Short time to market allows putting quickly products in the market and being competitive in the sector. A company with long time to market faces the risk to be cut from the market because the product it introduces has been replaced by competitors' products, it is no longer attractive or maybe it results as old fashioned or obsoleted. Time is related essentially to three components:

- time necessary for the execution of the activities, such as the design stage in CAD;
- time lost between the activities, for instance when the activity is concluded often it takes some time to move on the next stage because it is waiting for approval;

- time lost in redefining and working again on tasks already completed because data were lost due to the lack of a system of management of the history.

PLM system has the main advantage to shorten the product development cycle. It accelerates the activities by giving instant availability of data when required, it gives access to all the people inside an organization, in particular managing the authorization on the contents, it shows updated files preventing to work on oldest files, it supports the management of parallel activities and shows their status.

One of the main problems in design and development stage is dealing with many information and different format files. Historically, a designer uses 25 to 30% of his time just to manage information: searches, waiting for copies of drawings, storing of new data. Often, he prefers to start again rather than to recover the elements of an existing project. This retrieving activity is considered unproductive and does not bring value.

A PLM system avoids dead times because the designer no longer needs to know where drawings or issued data are, but he can simply have them by querying the system. The advantage is to have greater productivity in the design phase. PLM gives the right tools to access data with maximum efficiency, therefore the design process can be drastically shortened, increasing the time available to designers to carry out the design. In addition, by storing projects data, they can identify and reuse those files for similar projects.

The adoption of an integrated system that covers multiple areas enables greater precision in the project and production. In fact, employees working on different departments have access to the documentation of another department, even if it is not of their competence and they can use it to check the activities progress or to retrieve information that otherwise should ask to others. This assures that everyone involved in the development process can operate on the same data set but only the right operator can modify the content while the other can access a copy for consultation. The system allows designers to work in parallel on complex structure of data, reducing the risk of inconsistency and duplication of data.

Another topic, often forgotten, is the creativity aspect of the work. It is a fundamental to have it and deploy it in presence of a new product development project. However, designers have a conservative approach to problem solving and that happens because the exploration of alternative solutions is considered risky and could lengthen development times. On the contrary, PLM encourages the creativity in finding new design approach and sharing ideas,

thanks to the electronic file transfer and distributing of the same set of information to all participants.

New product development is characterized by long period before the release of the product. Sometimes, it is not attributed to bad planning, but it is often due to a gradual loss of control of the project. Management capabilities are not sufficient in dealing with thousands of data, changes, delays and unexpected variables. Firms lose control on activities and development projects are traditional on delay.

PLM systems make it possible to manage the project effectively, ensuring close monitoring of data and information traceability. Particularly, data related to the product structure, changes, configurations and all those scheduled activities, which are impossible to forgot or ignore. Product data management systems should not be restricted to contain in the database a complete representation of the current status of the project but must also record all the states through which the project has transited, in order to use them for post assessment and also for avoiding similar errors in future.

1.3 The economic impact of fashion system

The fashion industry is an important sector in the global economy. Revenue in the fashion segment accounts to almost US $600,000 million in 2019 and is expected to show an annual growth rate of 11.5% for the period 2019-2023, as showed below. [3]

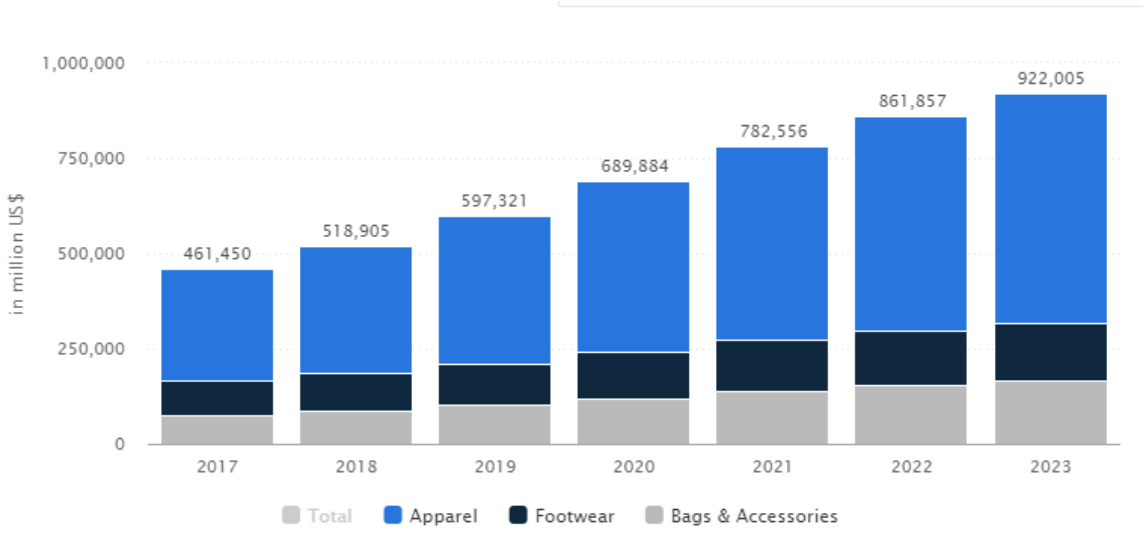

Figure 1. *Revenue 2017-2023. (Source: statistica.com)*

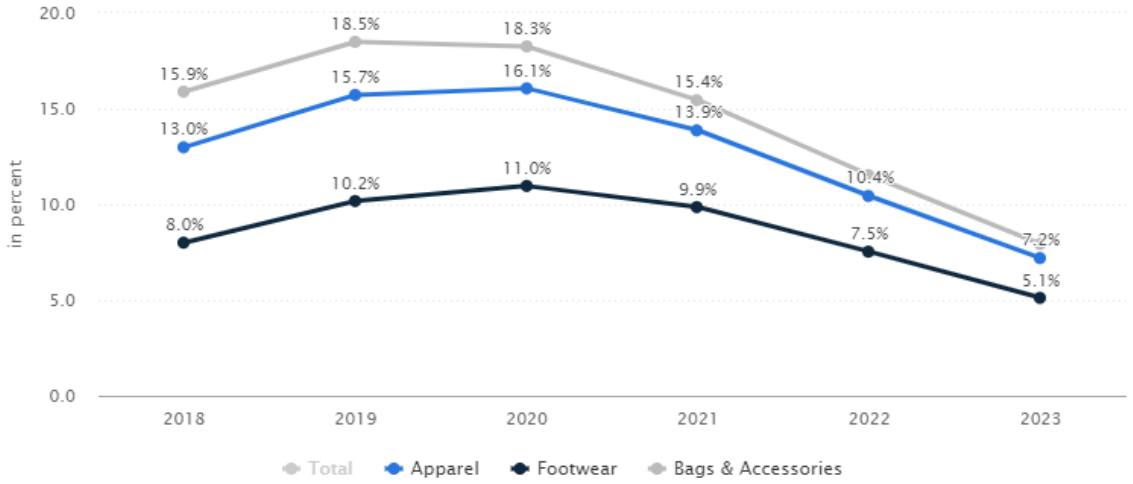

Figure 2. *Revenue growth 2018-2023. (Source: statistica.com)*

The figures show high numbers for the two indicators since this sector is one of the most productive. In the first figure, we see that apparel sector has the highest revenue compared to footwear and bags and accessories. As concerning the revenue growth rate, it has reached the peak in 2019 (18.5%) but is expected to decrease according to estimates.

The factors that have allowed such growth are many and they need to be associated to economic, cultural and technology changes. Thanks to the falling of raw materials' costs and production costs, the streamlined operations with new technology tools and the rising consumers' spending, clothing production has grown enormously. People buy garments not just because they need them in their wardrobe but for the desire to have the last fashionable garments and follow the upcoming trends. The high availability of garments of every model, size, colour, style and the affordable price affects the consumers' behaviour who continue to feed this industry.

According to the source, today the world consumes about 80 billion new pieces of clothing every year. This represents almost the 400% more than the amount consumed just two decades ago. [4]

As we have seen, fashion industry is a continuous growing industry and represents an interesting sector to analyse. However, it is still a traditional sector which has not reached the technological levels of other sectors. For this reason, it is interesting to analyse it on a technological point of view, exploiting existing technologies and analysing new growth opportunities.

1.3.1 Market requirements

Market represents a dynamic environment and particularly in recent years has become more challenging and characterized by many trends. In order to sustain the growth and survive in the market, companies must invest in their businesses and further consolidate the brand image. It essential to adopt a specific corporate strategy that helps the company to define its identity, where it is positioned, what it wants to offer and who are its customers. The added pressures, brought by several factors, drive companies to quickly reorganise themselves to meet market requirements. Some of them are described below and constitute key success factors for fashion industry. [5]

- Globalization. Originally, it was concerned with movement of labour and capital across nations based on comparative factor costs and productivity for labour, capital and other inputs between nations and their impact on product costs, changes in international exchange rates, quotas and tariffs. Now, it is related to some other aspects of distribution in addition to the previous ones, such as lean retailing, product proliferation, onshore and offshore outsourcing. Globalization affects the textile industry throughout the production, distribution and marketing channels. Companies have to balance worldwide market with local needs of the areas in which they operate. Today, people are updated on new trend in the fashion industry through old and new media like radio, television, newspapers, internet and mobile phones, hence the need to introduce new products globally. [6]
- Supply chain management. With the globalization and the outsourcing of production on a constant rise, companies have an increasing need to manage and integrate internal operations and also external processes. Sometimes, companies turn to external suppliers for specific production phases or for the entire production cycle. Handling a production process in the most complete and effective way means be able to monitor orders and suppliers, provide correct data, use tools for collaboration and sharing of information between parties and have chain management expertise. We may consider as an example the Spanish company Zara that, through its innovative business model and supply chain management, has become one of the most successful multinational company of the last years.
- Digitalization. The digital movement is bringing about greater price transparency, increasing the potential for product refreshment and adding pressure on margins. As said before, the digital age is gradually changing the way to collect product information

and find the best deals. With easy access to the Internet on smartphones, consumers no longer solely depend on stores for shopping. They have access to online portals dedicated to price comparison and consumer guides to find the same product at different prices and they can read other users' reviews, which influence purchasing decisions. The introduction of new tools, such as platforms for shopping and social networking sites have given more power to customers. If on one side digitalization could have negative impact on traditional companies, on the other side, digital channels can be exploited by companies to reach their customers, get more visibility, advertise and get precious information about them, with the final objective of sale.

- Omni-channel. Nowadays, companies have multiple channels to sell and distribute their goods. Brick and mortar stores should be integrated with e-commerce, a web space in which the enterprise gives a strong brand message to its potential customers. On the other side, it enables customers having a clear vision of what the company offers and they can be connected with the brand anywhere, any time, on any device. Omni-channel retailing means identify all the customer touch points, those include all the social medias, and offer cross channel solutions, such as "buy online and pick up in-store", "reserve online and try-on in-store", "order in-store and pick up in another store" and all the other possible combinations. The objective of a company is to be more flexible and give alternative services to its customers, in order to build a close relationship and improve the loyalty of its customers.
- Time to market. Time to market is a crucial factor for a company that is in fashion industry and it represents the time necessary to create, produce and distribute new product collections. The marketplace is dominate by main players that compete in time. Being on trend no longer guarantees sales and profitability in the fashion sector. Thanks to the Internet, in few minutes, consumers can spot and share a trend on social media that will be visible from any corner of the globe. This will probably increase the sales of products relating to that trend; therefore companies have to move rapidly in exploiting that trend and introduce products in line with the customers' needs. The point is to understand how companies can reduce the time to market and which practices must change to obtain better performances. [7] According to a study done by McKinsey, we see that top performers in the market of fashion are using strong data analytics and consumer insights from the first stages of the process of new product introduction. In details, they start to apply data analytics at the beginning of the product-design process when developing concepts and planning line, right inside the heart of the creative

process. Traditional companies and underperforming companies start the analysis and manipulation of data much later in the process, only after they have developed the product with all its features. The traditional approach is to focus on the design of product, lines, colour, materials, fit, accessories and, once the design collection is ready, it moves to the market analysis, with the creation of the size range and variants of the models based on estimates made. For top performers, the speed of the market has become one of the major top priority and now they can deliver product to market in less than six to eight weeks. In the past and even today for some traditional companies, the typical lead-time in the industry is more than 40 weeks, in which the design of the collection begins even one year before the launch of the collection in store and the production starts almost six months before. The other element taken in consideration by the top market players is customer insight. In the past, it was not considered at all, customers simply had to judge at the end of the process if they liked the collection and give their opinion simply by buying or not the product. Today, consumer's opinion is extremely important and is also considered in the first stage of product development. Firms look at their typical customers, what they like, what is their lifestyle, what they usually buy and track their feedbacks on social networks, blogs, firm website and e-commerce and combine this information with data of previous collections and sales. Actually, few companies are taking advantage of the multiple insights across their business and many of them rely on a single source of insight, such as sell-through data or product rankings. On the contrary, those who have adopted a data-based decision-making approach based on understanding what the consumer wants, are capable of quickly response to the market's needs and generate early sales.

- Flexibility. The existence of several factors, such as the financial crisis, are boosting economic volatility, which demands firms to be more flexible in operations to meet market demands, especially in international markets. Flexibility can help boost sales, efficiency, and reduce costs and allows a firm to react to market changes rapidly and in the most effective way by the optimization of the resources. As described above, a flexible supply chain is necessary to manage the production and distribution of goods, the optimization of the processes and the allocation of resources to reach high level of performance. Flexibility means also the capability to introduce new technologies and innovation inside a business. The first requirement is to have an automated supply chain system. Flexibility in reaction time is only possible when a company is able to manage data and obtain information quickly. There are common situations for any company

within the retail sector that can be dealt with, in a timely manner and with minimal impact, when the processes are completely automated. For instance, when there is an unexpected increase of the production of a certain product following the launch campaign or there is a stock-out of a product in a particular size which needs to be immediately replenished, a firm should face these issues and be ready to market changes. A company can address these situations by adopting the right working methodology. [8]

- For instance, in the last years, the concept of working agile has been spread among all kind of industries. The agile approach launches a new model, a new way of working by doing and refining, rather than mapping and redrawing the entire processes within an organization. Companies learn by doing and make rapid progress by putting in charge a top team and demonstrating that they can design and deliver at speed in a single season.
- Engagement. "Customer engagement is the ongoing interactions between company and customer, offered by the company, chosen by the customer". This is how Paul Greenberg has written on HubSpot, but there are many other definitions of the concept. Companies create touch points with their potential customers and improve the relationship, trying to understand what they desire and what is best to offer to them, improving the communication and offering new products and services. What is unusual is the last part of the definition, which explains that the customer chooses to interact with the brand and this represents the news. The role of the consumer has shifted from a passive observer to an active player. He wants to interact, belong, influence and be the brands from which he buys. Informed, selective, and in charge, he cares about how he look in public and on social media, and about the perception of the goods he buys and owns. The vast majority of consumers use digital channels before, during or after their purchases and so they can feel to be part of the process too. It is clear that a firm success is determined by its customers and not by the product itself. One of the ways by which firms build the customer engagement is by improving customer journey, namely the experience he lives in the process of buying. By customer journey mapping, a company looks at all the possible use cases, it designs the process and adds smart solutions to give customer a good buying experience, by tracking and presiding over all possible touch points that the user could have with the company. Currently, what is most challenging is to find the right strategy and tools that allow correctly following the complicated and unpredictable journey of the client. A firm could not able to improve the customer engagement if it does not monitor and measure it. There are several ways to collect data,

make an analysis and get some conclusions. For instance, we could measure the guest checkout rate (the number of customers who complete a purchase without making an account) and compare it with the total number of orders. If this number is low, it means that the majority of customers make orders from their personal account and this suggests that when a customer creates an account, they are more likely to come back to make another purchase and become regular customers. Another indicator is the purchase frequency that tells how often a client makes a purchase at the store or at the website. By knowing how long it takes the average customer to make another purchase, the firm has a better understanding of how engaged they are.

- Sustainability. Last topic to include in the list of market requirements, the most recent one, is the sustainability and corporate social responsibility. The fashion industry is not sustainable in its current form and the environmental footprint is accelerating due to raw material consumption, carbon emission, pollution and waste. Lead by the desire for newness and variety, customers' purchases have rapidly changed. Today, more than ever, consumers are buying more clothes and keeping them for less time. Global production has more than doubled in the past 15 years and there are some worrying data on the current consumption of resources. [9] The circular fashion is imposing itself as a trend, but it will be one of the necessary market requirements of the future. Fashion industry needs a circular system and a new business model while, on the other side, consumers are increasingly aware of the environmental impact of the industry and expecting new solutions. The type of model is an open question until today: recycling material, rental or re-commerce or other combinations of business models. Unfortunately, the scale of this progress is not yet sufficient to offset consumption growth and reduce the environmental impact and companies are in search for an understanding of the financial viability of circular models.

Chapter 2

2. Pattern S.p.A.

Pattern is a company founded in 2000 by Fulvio Botto and Francesco Martorella which today represents a landmark for top-end luxury fashion engineering, particularly in the outwears and sportswear segments for the most prestigious luxury fashion brands worldwide.

It was born as a business idea related to the fashion sector, characterized by activities implemented vertically within the company: design, engineering and garment development, starting from a service of prototyping and then of realization of samples, arriving finally to the production of the garments on behalf of the most important international brands.

Pattern operates in an attractive market segment, the made in Italy absolute fashion manufacturing, in a competitive landscape dominated by a large number of small local players not in direct competition with it in a highly fragmented market. The company is based on the values of quality, flexibility, speed and reputation and is considered a market leader in innovation. In fact, in the last years it was concentrated in research and development, having a solid focus on technology and innovation.

Followings, an overview of Pattern's business model.

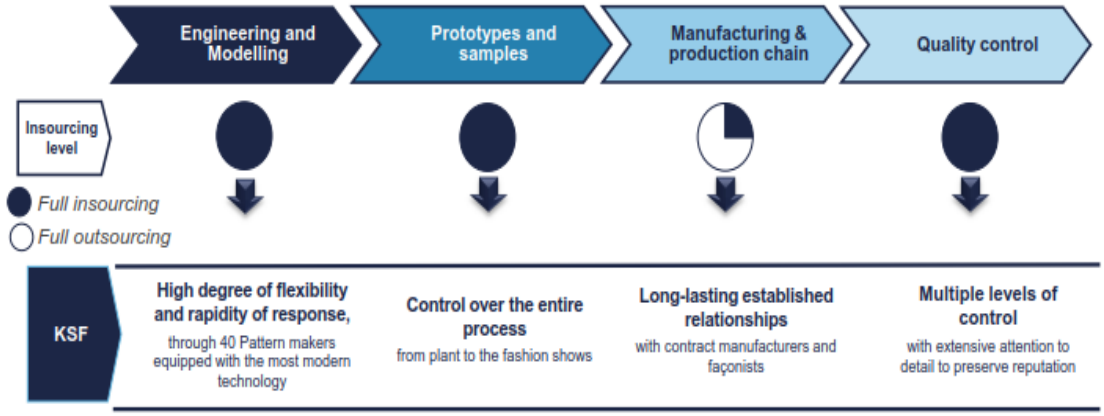

Figure 3. *Investor presentation, September 2019, (Pattern.it)* [10]

As shown in figure, most of the processes in the value chain are carried out internally by the company: the engineering and modelling, the creation of prototypes and samples and even the quality control are fully executed by the company, except for the manufacturing, in which

Pattern relies on contract suppliers for the sewing of garments, who are certificated and with whom it has a solid relationship.

2.1 General assumptions

Following, a detailed analysis of the development process of a new collection in Pattern is described, starting from the first phase of receipt of the order by the customer until the final shipment of the order. Usually, luxury fashion companies turn to third parties to make the garments of their collections. Following, they will be indicated as the client. Pattern is a successful provider who takes care of the engineering and production of garments and accomplishes companies' orders.

The client develops the collection that consists of several sketches: basically, the designers make the drawings that define the style, the material, the colour, the lines, the shapes of each piece of the collection. They are called "figurini" and usually they are 3D drawings. (Fig. 4)

Figure 4. *Burberry tight sweater. (Caroline Andrieu)*

They are shared with suppliers and distributed in time, together with the technical specifications. If a collection has many pieces, the supplier will probably receive the sketches in 2 or more different times, usually by e-mail. We can state with certainty that the planning phase of the collection and development of the concept are performed almost exclusively by the customer, with the exception of some suggestions that come from the supplier as soon as he inspected the sketches. For example, thanks to its experience, he knows that the combination of those types of materials chosen by the client are not fitting well, so it could suggest a slight change.

2.2 New collection development in Pattern

The process inside Pattern can be divided into three macro areas: *planning*, *development* and *production*:

- The *planning phase*, as said above, is attributed to the fashion house. Planning starts with the review of data derived from market analysis and leads to the creation of a first and extensive set of models that could be part of the collection.
- Once Pattern has received the orders from the client, *development phase* begins. The latter is divided in two sub phases, prototyping and sampling that lead to the creation of the physical garments. In fact, through an iterative process of modeling and control, it chooses the models and the relative variants that will go in production. In particular, in the prototyping phase, employees make a first draft of the garment while in the sampling phase, employees make a garment in one size only for the fashion show or for the pre-collection.
- Finally, in the *production phase*, approved garments from the collection are produced in the whole range of sizes and variants and distributed in the market.

This process breakdown is also reflected in the project management software that the firm uses for shaping and monitoring the whole process. *PM* is a module used for the management of a project, mainly used by manufacturing companies. The figure below shows three macro areas related to prototyping, sampling and production stages.

Fase	Attività	Totale giorni/fase	Totale giorni/prodotto	Gruppo utenti	Utente	Data di inizio	Scadenza
01	1-Inizio Prodotto	35	3				
01	1-Creazione Scheda Prodotto	40	3	PRODOTTO MU			
01	1-Modellatura	40	3	MODELLI UOM			
01	1-Lancio	40	3	PRODOTTO MU			
01	1-Piazzamento	40	2	CAD PIAZZAME			
01	1-Taglio	40	2	TAGLIO			
01	1-Preparazione Commessa	40	2	MAGAZZINO			
01	1-Invio al Confezionista	40	1	SPEDIZIONI			
01	1-Rientro da Confezionista	40	1	SPEDIZIONI			
01	1-Spedizione Cliente	50	1	PRODOTTO MU			
01	1-Approvazione	50	10	PRODOTTO MU			
02	2-Completare Info Prodotto	45	3	PRODOTTO MU			
02	2-Modellatura	45	3	MODELLI UOM			
02	2-Lancio	45	2	PRODOTTO MU			
02	2-Piazzamento	45	3	CAD PIAZZAME			
02	2-Taglio	45	3	TAGLIO			
02	2-Preparazione Commessa	45	1	MAGAZZINO			
02	2-Invio al Confezionista	50	1	SPEDIZIONI			
02	2-Rientro dal Confezionista	50	1	SPEDIZIONI			
02	2-Spedizione al Cliente	60	3	PRODOTTO MU			
02	2-Approvazione	70	1	PRODOTTO MU			
03	3-Registrazione Ordini	70	25	PRODOTTO MU			
03	3-Completare Info Prodotto	100	10	PRODOTTO MU			
03	3-Modellatura	105	15	MODELLI UOM			
03	3-Sviluppo e Taglio Dime	115	15	CAD SVILUPPO			
03	3-Pre Lancio	115	10	PRODOTTO MU			
03	3-Piazzamento e Consumi per Lancio	115	5	CAD PIAZZAME			
03	3-Taglio	120	3	TAGLIO			
03	3-Preparazione Commessa	120	2	MAGAZZINO			
03	3-Invio al Confezionista	120	2	SPEDIZIONI			

Figure 5. *Collection planning, Pattern S.p.A.*

Each area, highlighted with a colour, contains many activities. The latter are assigned to a user group (department) or to an individual user (person). This software also allows tracking all the activities performed inside the enterprise, showing information about the actual status, progress and the dependency relationships between the activities. Before the introduction of the PM tool, people had to report the information into Excel files and each department had their own documents. There was no good sharing of information and data were not updated well. The introduction of the software has allowed to integrate the data and the flow of activities, having an overview of the system available to everyone in real-time.

When the firm receives a customer's order, the first thing to do is to insert the input data into the system. Employees create a tab for the collection to which they associate a code. Inside the collection tab, there will be all the models with their codes and specifications. Each model is identified by three attributes: the *type* indicating the status of the model (if it is a prototype, a sample garment or a production garment), the identification *code* (that is assigned according to the collection, the brand and the type of garment) and, finally, the *phase* (which indicates if the item is in the prototyping, sampling or production stage). Furthermore, the tab of the model contains information about the type of garment (suit, trousers, skirt, etc.), the range of sizes and other information about clients.

There is another tab, called the product tab, which contains more commercial information, like the list of all the materials used to produce the garment, fabrics, accessories, label and package to deliver the product. The main fabric of the garment is usually sent by the customer with the respective specifications, while the rest of the fabrics and components necessary for the production of the model is managed by Pattern. In addition, the tab contains information on the sales campaign and status of the activities.

The creation of a complete tab for a model starting from the sketch is not a very long activity, it usually takes a few minutes, but interpretation is needed by employees who build the input data starting from drawings that are very linear and basic. In fact, the 2D models of the single pieces that will compose the finished garment are extrapolated from the analysis of the sketches sent by the designers. The pattern makers perform this activity, by creating the patterns, the basic fabric units that make up the garment.

Once the model and the product tabs are ready, the model office takes care of designing, engineering and 2D modelling of the products. Modaris PGS is the software released by Lectra and used for the CAD design. It allows both the design of the models and their size

development. This program allows the creation of the model using points, lines and geometric shapes and is similar to CAD software used in other sectors. The use of 2D CAD tools simplifies the drawing process, as it is sufficient to define the most important points of the garment with the necessary references, but it is paramount the designer's experience in using these tools to create correctly the model.

Then, with the CAD 2D files, the bill of materials and the tables of measure, the product office can make the launch. In this phase, employees make some variants of the model, trying to adapt different fabrics, colour and motifs in the same model. Therefore, this activity defines the type of fabrics and components for a model and, once established, it passes the list of withdrawals of materials in stock to the ERP software, called GAMMA. The ERP takes over the information and generates a file for each product, called the "Z sheet", which contains the bill of materials (BOM).

As concerning the procurement, there are two separate branches. Most of the fabrics, especially the main fabric that will make up the garment, come directly from the client, while complementary fabrics and other components, such as buttons and zippers for example, are handled by Pattern. Therefore, the product office takes care of client-side relationships, while the purchasing office deals with supplier-side relationships.

After the launch, the marker making is performed through a software called MARKA. The marker making consists in setting up firstly the marker planner, which indicates the precise make-up of the marker plan such as the fabric width, the pattern pieces to be utilised, the product sizes to be included in the marker and other constraints to be considered. Then, it defines the optimal placement of the pattern pieces in the marker previously planned in order to have the highest marker efficiency. The following figure shows the activity described.

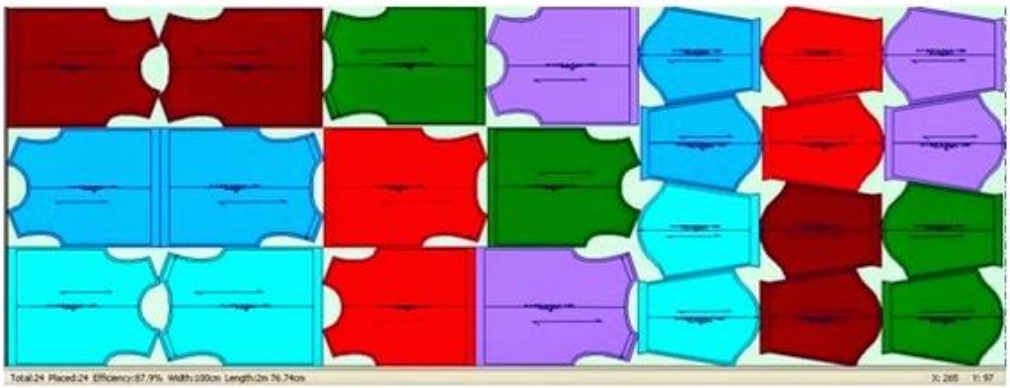

Figure 6. *CAD marker making.* [11]

In conclusion, the marker making gives information about the textile consumption and generates the cuttings sheets, which are communicated to the department in charge of the cutting of fabrics.

The cutting phase could be automatic or manual, according to the type of fabric or pattern. For automatic cutting, through technologies of type CAM (*Computer aided Manufacturing*), it is possible to use the files created with the CAD software and send them directly to the machinery used to the production, like plotter, automatic cutting machines, laser cutting and others. Therefore, these cutting machines needs to be integrated with MARKA, the software for the marker making, to obtain indications on cutting sheets. When the fabric presents particular prints or texture, as checks and plaids, manual cutting is used instead. If the fabric is rich in details, the waste of material increases much compared to a standard fabric and so it is much complicated to make the marker making in CAD because the software does not allow considering the specific characteristics of the fabric. In this case, it is done manually directly on the fabric, as well as the cutting.

After the cutting, and with the material consumption information, all the data are available on the ERP. Employees assigned to the warehouse can prepare the order to deliver to the suppliers. It consists of all the cut fabrics and accessories to sew together for making the garment, the client's sketches and other technical information about sewing. Then, the ERP creates a delivery document (DDT) linked to the order, which is shipped to a supplier for the sewing.

Once the sewn garment is ready, the supplier delivers it to Pattern and, on return, the garment is inspected by the testing office to detect the conformity of the product and any possible defects, before being shown to the customer. All the activities described above led to the creation of the prototype and, with the client's inspection, the prototyping phase ends.

For the client's inspection, also called fitting, the client is invited to come in Pattern or he can receive the finished product directly in-house. During the fitting, he takes decisions about the product, like approving it, making some changes or give up the product because it is not as expected. Any client's decision is reported in the system: if he approves the prototype, the firm can step forward to the sampling phase, otherwise it has to reiterate the processes with a new prototype. In particular, if the modifications that the customer asked on the prototype are consistent, then, a new prototype is started.

The sampling process is an iteration of the prototyping process after the customer's modifications, with the only difference that, in this case, Pattern begins to think in a future

perspective of production, since the garment has received a first approval. Until now, the prototype has been produced in a basic size, so there is no information on the whole range of sizes and the consumption of materials that could generate in different sizes and there is no sales information since there are no orders yet.

Once the sample is inspected and approved by the client, the production of that garment can start. In fact, with the conclusion of the sample phase, the sales campaign begins and it needs the information regarding costs in order to generate the production orders. The cost is based on three factors: the fabrics and components consumption related to the garment, the working cycles performed on the pieces, such as the cutting, the sewing or eventual embroideries, and finally the multiplier factor, which is the percentage increase of the cost in function of the requirements of marginality and profitability of the firm. Here, it is important to remark the integration between the tools for the creation of the price lists. In fact, the working cycles of every product are traced on PM but must be exported on the ERP in order to generate the costs and the pricing list.

A production sheet is created with all the product references. Moreover, the firm has received the orders from the client and so it can move to the size development phase. As said before, the prototype and the sample have been done in a standard size. All the patterns are drawn taking a single size reference, which is called basic size, from which all the other sizes are derived, without changing the shape of the model. Now, each model must be developed in all range of sizes, according to the collected orders. This process has not been automated yet and the company has developed its own logic.

First of all, employees create the CAD pieces related to the whole range of sizes. Then, a pre-launch is done to obtain a point estimate of the material consumption of the garment for each size. Subsequently, cutting sheets are created. Inside the marker making, pattern pieces of different size garments are placed in order to optimize the fabric consumption. Once the cutting sheets are ready, it follows the cutting phase, the delivery to the suppliers for the sewing, the return of the finished garment to the warehouse, the quality control and the final delivery to the client.

For the material requirements and supplies, the firm begins the activities before having reliable information about orders and material consumptions. At the beginning, it has only the sample sheet with the consumption related to the standard size of the garment. Assuming an average consumption to split among different garment sizes, it has defined a mark-up coefficient to

apply to the known consumption in the standard size. The mark-up coefficient derives from a prior analysis of the fabric consumption of past collections and the sizes sold for the various product types. Trade-off between efficiency in the purchases and risk of cancellation of the orders has led to the selection of the best scenario. The sizing process is not completely formalized and the cost of raw materials is borne by the company, so it applies its knowledge and past experience to handle it, avoiding waste.

2.2.1 Activities and departments

The *pattern department*'s job is to shape the idea from the sketch of the designers. Thanks to company's know-how, they find the perfect combination between the idea of the designer and the best processes and technical solutions, helped with new software applications. The *product development department* interfaces with customers and take cares of every phase from prototype managing, the production launch and to the trimming of the apparel and the textile. The *CAD department* creates the CAD patterns, accomplishes with the placement of all textiles and fulfils all technical documentation refereeing to the cutting process. The *warehouse department* arranges the trimmings related to garments and provides the textiles for the cutting process. After the cutting process, the first prototype is made in the laboratories. Prototypes at this point are shown to the customer for fitting, last check and approval. Final prototypes with all the changes decided by the client constitute the sample. Collection are launch at runways, show rooms and fashion shows and then Pattern subsequently manages the production orders for final distribution.

2.2.2 Operational risks

According to the nature of the business, the company has to face many risks linked to the production and daily activities. Here are some examples:

- Risks related to relationships with external manufacturers. For the production of their own garments, Pattern turns to a selected group of suppliers, mostly certified by house brands and in any case managed according to the SA8000 rules. In order to prevent the company from becoming too dependent on certain suppliers, the company is constantly in search of new sources of production. Additional risks with external manufacturers concern quality control and compliance with delivery times. Both of these themes are

of strategic importance for a company that operates in the highest market segments of fashion. For this reason, those risks are constantly under the observation and control of the management.

- Risks related to the availability and supply of raw materials. The raw materials are mostly purchased in agreement with the final customer, but in recent years the company is bearing more risks relating to the purchasing of fabrics. For instance, the cost related to garments cancelled or not sold, the cost of making prototypes and samples that will not go into production and all other wastage typical of the textile industry. Moreover, the cost is not considered in the early stages of the process but once the sampling phase begins, with the definition of the price list. Therefore, the first part is load of Pattern, who executes the work without a precise control of the costs but with the final objective of delivering conforming products that match customers' requirements and that will be select be to go in production.
- Risks related to the selection and retention of qualified personnel. The peculiarity of the activities carried out by Pattern and the high specialization of jobs makes it difficult to find experienced personnel in the most technical functions. However, the growing success of the company has made it possible to consolidate the relationship with key figures and to attract younger resources.
- Risk related to the garment production. The peculiarity of the textile sector and manufacturing process implies that there are no standard products. Each garment is designed with new shapes, textiles and styles and needs to be new for the market. The main issue with make-to-order production (MTO) is that the supplier has to deal with garment production case by case. For example, a fabric chosen for the garment has specific properties and must be treated in a certain way, with specifications for the cutting activity. The fabric could show some defects which are not detected by software and so the people expertise is necessary to arrange the cutting phase in order to find the best efficiency in material consumption that an instrument alone cannot guarantee.
- Risks connected to the obsolescence of the informative systems and IT tools. Pattern invests annually important resources for the continuous updating of its CAD system and for the development of computerized procedures. The theme is relevant since the company carries out internal activities of engineering, design and production management. The adequacy of the information systems makes it possible to respond to customers' needs and market requirements.

In particular, last topic will be examined in depth and will be the subject of the next paragraphs.

2.3 Analysis of management tools in Pattern

The adoption of specific tools has a strong impact on the performance of the company and it defines the type of business, the activities on which it is concentrated and the market segment in which it is placed. The management structure of an enterprise must be aligned with its strategic objectives and it is important that its infrastructure reflect this. PLM represents an integration of different software applications, divided into several modules, whose degree of application in a company determines its degree of technological innovation.

Pattern uses a series of core tools that allows it to manage tasks and coordinate activities. As mentioned above, the IT tools used by the company can be grouped as follows:

1. PM is the project management tool and it is one of the main LECTRA instruments. It gathers in itself the monitoring functions and shows the production progress, allowing the integration with other LECTRA modules. It allows creating the Master data and codifying the workflow, models, product, materials, customers, suppliers and so on. Therefore, its main function is the traceability.
2. LECTRA software are specific solutions for the fashion industry that provide a complete spectrum of design, development, and production solutions. Pattern owns three packages:
    - PGS CAD is used for computer modelling, digitize, archive, edit, develop sizes and create 2D pieces of a model. In addition to the management and sharing software, firms need a software that allows the design and development of an object by computer;
    - GENMA is the management software for Lectra database and contains information about models and cutting sheets. Its function is to combine and store data from CAD and MARKA in a unique database. In synthesis, it is the CAD objects administrator and is used, for example, to rename a model.
    - MARKA is used for the marker making that is the optimal placement of the pattern pieces inside a single fabric to find the optimal material consumption and specifications for the cutting phase. This activity lead to the creation of cutting sheets which are then directly used as input by automatic cutting machines.

3. GAMMA is the ERP, the management software that, with its modular setting, provides the tools for a complete management of the company's activities such as sales management, purchasing, accounting, production budget, industrial accounting, planning and management control. The software is used for warehouse management and documents issuance and it is integrated with PM from which it gets the information on project progress.

Chapter 3

3. Enterprise software

Product Life Cycle Management (PLM) represents a strategic approach to the management of information, processes and resources in support of the life cycle of products and services. PLM is not just an integrated approach but also a computer technology, based on a set of applications and methodologies for collaborative work organisation and process definition. We can say that PLM is the result of a set of technologies on one side and corporate behaviour on the other side. Only the correct analysis and commitment of the company to act on both these levels, in fact, can guarantee the success of a PLM project, not just the right technology.

Until today, PLM represents an emerging paradigm and is being assessed in the manufacturing, energy, defence, pharmaceutical, chemical, food, textile, clothing and many other industries. Insofar, the market is fragmented and there is no leading technology.

Indeed, the market offers many solutions and is dominated by different players who offers their solutions, which sometimes are specific for the sector. In fact, listening to the companies' needs, several vendors, coming from diverse worlds interested in the product and production management, are more and more providing solutions, by establishing a growing PLM market. According to [12], the analysis of the ICT market and software solutions, which are already adopting the PLM, shows the following trends:

- vendors coming from the digital engineering world (Siemens, PTC, Dassault), which start from PD (Product Development) and MES (Manufacturing Engineering Systems) processes, are trying to connect Enterprise Engineering and Management processes;
- vendors coming from the ERP world (SAP), which, at the contrary, start from Enterprise Management processes and try to link them to PD/MES tools and platforms;
- vendors coming from the ICT world, which aim to establish collaborative environments for PLM integration (Microsoft, Agile), are using web technologies.

The choice of the right tool depends on how the company manages the information. PLM is not an ICT problem, but it is related to the strategic business orientation of an enterprise. Firstly, a company has to deeply understand its business and what are its core competences and primary needs, making an analysis of the organization and the relationships between internal and

external players. The analysis should be done following three different perspectives: strategic, operational and human dimension. After that, it can choose the solution that best suits its business.

Some companies make the mistake of believing that implementing a PLM system in a company means introducing a new software and so they focus on the choice of such software. However, the focus should be on process analysis, not on the software itself. A PLM project means analysing, understanding and improving the product development process and representing this process in a computer system so that it is easy for anyone to sharing information and collaborate with everyone else to make the product.

3.1 Basic functionalities of a PLM software

The first functionality of a PLM software was the electronic database. A single physical archive, which nowadays seems obvious, was a novelty in 1980 when there was still a multitude of operating systems, proprietary networks and few communication standards. The first systems were able to organise a logically unified archive, but physically split on different hardware and operating systems, which allowed to automatically move the data on different media, such as magnetic or optical drivers. Nowadays, the recent systems are based on the principle of indexed storage of a digital document. Each document is associated to a record in which there are fields with information related to the contents of the document. This facilitates the document search speed and the time of re-use. The user will not have to remember the document placement coordinates in the company server, but it is necessary only some information to get the document. [13]

A PLM system should allow revisions, variants or new versions of a file or a product. Every business document, since its creation, is normally subject to evolutionary changes, the revisions, or due to customer requirements, one product can have multiple variants, which may be in the sense of colour, configuration contents or other aesthetical characteristics. When the modifications applied to the file are significant, it constitutes a new version. A change management system allows users to access with certainty the last approved revision of a document and, at the same time, record all the previous files. This means to have multiple instances for the same object realized later for reasons of correction, errors or to satisfy other requirements. A PLM system must allow the creation and management of each instance and

must be able to select a specific version of the component, among the various existing, to use for a given product.

Another fundamental requirement is the management of the structure of the product. At the design stage, the structure of the product itself is defined at a certain level of detail with the logical decomposition of the product into systems, subsystems and components, the so-called bill of materials. Managing the product structure for a PLM means allowing the creation and maintenance of relationships between objects and their validity criteria, for example by type of bill, by time period or by effectiveness. It also means being able to perform collective operations on a subset and maintain the integrity of the data even if they are partly created and modified in CAD systems.

The integration with CAD systems was one of the first functionality implemented in a PLM environment. CAD software is a tool that allows the design and development of a product through computer. In particular, there was the need to automate and facilitate data exchange between the two systems. Sometimes, data exchanges between CAD and PLM software are not so smooth. The first requirement was to facilitate the retrieval of data in the archive and the activation of the CAD session on them. Designers and manufacturers operate daily in extremely dynamic environments. When the product is in the development stage, there can be significant changes to designs, forecasts and marketing plans. If CAD and PLM systems are not well integrated, these changes must be updated manually within each system and this activity results as time consuming and subjected to errors. On the contrary, if a CAD system stores markers and patterns in a relational database, it facilitates the native integration. Moreover, in the last years with the emerging collaboration needs, the work has been reorganized to allow several people to operate on the same data, in different physical locations and at the same time. With integrated CAD and PLM systems, when markers and patterns are edited and saved in the CAD system, they automatically refresh data in the PLM system and are accessible even for operators that do not work in the CAD environment.

Another function of PLM is to allow users to manage the technical modifications to a product or component. According to a change management approach, when a modification occurs, it must be adjusted and formalised in the design environment. Therefore, it is possible to have a full traceability of the previous changes, when they were made, who made or approved them and assess the overall impact of the change, the production costs and the inventory. A PLM system makes operations traceable and allows reconstructing the passages through which

decisions have been and, in some sense, it makes mandatory to comply with internal procedures and quality standards that the company imposes.

A system rarely exists alone but very often it is part of a complex ecosystem of business information and therefore it must necessarily integrate and share some of the data with other enterprise systems. Organizations usually invest in several best-of-class systems to accomplish different business objectives. This creates a heterogeneous IT landscape in which it is important to manage the flow of data from one system to another.

When the first PLM system is brought into use in a company, it does not usually replace any specific old system but brings new surplus value to the infrastructure. This value is increased by the new properties and possibilities of the PLM system, which allows many old manual processes to be converted into automatic operations. Integration between systems and data migration is not an easy task. Integration must be the subject of a careful planning and decisions that often come from senior management. While for some commercial products, there is the availability of many software packages, which facilitate the integration, for others, more developments are needed by the software house. The analysis must be taken into consideration the relationship between PLM and other enterprise systems, such as ERP, CRM, CAD and other design applications, document management systems, reporting systems, sales applications, communication tools and all the other office applications of the company. [14]

Workflow is one of the main features of the PLM and allows managing the flow of information within the company so that each person in each department involved in any activity or decision concerning the product, can carry out its task quickly and have all the variables under control. Workflow is able to build-in a business logic and define standard processes, by enforcing best practices and eliminating errors. It shows the instant status about the activities, history and audit trails which ensure complete control and visibility of the processes. By mapping all the activities, a PLM system performs the monitoring of the process. It sends notifications of the progress and requests for approval to specific users, it attaches the relevant documentation, it enables electronic signatures and triggers any automatic status transitions. Furthermore, it defines user roles, group membership, access rights and signature powers. Sometimes, the workflow could be integrated with the email system to reach users who do not have access to PLM system.

Another important aspect of PLM is the management of configurations. A configuration is a unique identification of the object which defines the physical and functional characteristics of

the item that constitutes the product and identify the documents. A control on the configuration is necessary to ensure that the technical changes that are made are compliant and to maintain their traceability. The system should record all the changes applied at any time and be able to report on their state of application. Management of configuration allows meeting the demands of more advanced and differentiated products, without increasing costs, and provides maximum control of the BOM and relative documentation at any point in time in the product life cycle.

Many sectors require the classification of objects, for example design parts or purchasing parts. The main advantages of the classification are the flexibility in defining and redefining classes, the overlapping of classes, the ability to feed classification with diagrams and data from external sources and so on. Through a coding or classification system of items directly from the CAD environment, the designer will then have the possibility to automatically encode an item. A company can set its own coding rules inside the PLM and when a new item is created and encoded, it is inserted automatically in the archive of PLM and can be transmitted in real time to the management system through the integration software between the databases of different applications.

3.2 Software solutions for the fashion sector

In the last years, high fashion industry has become increasingly important as it represents one of the most profitable industry worldwide. Particularly, the Italian luxury fashion has always been recognised as excellence in the world economy.

Despite the growing importance of this sector, fashion companies still face many challenges in managing their products and in market competition. Although lagging behind other industries, in recent years, an increasing number of challenges have influenced these companies to focus on innovation to maintain or gain a competitive advantage. Successful companies operating in this sector must therefore understand and accept these challenges and find ways to address them through processes and solutions focused on innovation and development of new products.

Usually, the success of new products requires excellence in three areas, as reported in [15] , which are:

- the reduction in product development time, which allows the company shortening the time-to-market and gives the so called first-mover advantage, essential to be the trend leader;

- the increase in product development innovation, thanks to the use of advanced technologies;
- the reuse of company knowledge assets, which drives product development and reduces costs, avoiding repetitive mistakes.

Nowadays all enterprises have adopted different tools to manage the information. In this dynamic scenario, where products and services are continuously changing, entrepreneurs have to undertake the innovative paths on the way data are managed. In order to foster the development of an innovative environment, greater attention should be paid to intellectual assets. Most of the manufacturing companies became familiar with tools like *Product Data Management* (PDM), *Collaborative Demand Management* (CDM), *Customer Requirements Management* (CRM), *Enterprise Requirement Planning* (ERP*), Collaborative Product Development and Management* (CPDM) and, in recent years, with *Product Lifecycle Management* (PLM), that tries to cover all the functionalities of the others. All the instruments have the objective to centralize the information, managing data flows and maintaining data integrity. Many companies have acquired different tools over the years, representing separate modules, and now they find themselves with too many applications and duplication of configuration activities in which the integration of these different types of configurators could be really problematic. Before investing in new technology, the company should conduct an internal analysis on the current state of the system.

3.2.1 Internal analysis as preliminary stage

When a firm decides to change its organization from a technological point of view, the first thing that comes in mind is the heavy investment in assets, such as software and equipment. Before doing any investments, a firm should conduct an internal analysis as a preliminary stage to assess its position. Sometimes, new innovative technologies do not guarantee high performances but have to be accompanied by proper methodologies and the firm needs to apply a specific organizational approach in order to succeed in the sector.

By using a user-centred approach, thereafter, it is presented an objective analysis that can be done as preliminary stage to assess the firm and with the scope of mapping its processes and users. [16]. The study should involve stakeholders and users and their viewpoints, through which it is possible to analyse the business from different prospects. It is not enough to link all the activities to map the entire process, but it is also necessary to connect those activities to

users who perform them. This can result in interesting insights for the organization, since it can be more aware of its problems, weaknesses, improvements that can achieve with corrective actions but also strengths it owns.

An integrated IDEF0-based approach could be used to map the processes of *new product development* (NPD). This method enables to outline and link activities to users and tools. It studies the processes of a company, taking into account all the actors who participate in the activities, what role they play, what they do, which goals they have and how they interact with each other. Moreover, the model accounts for inputs and resources needed to start the activity and the constraints that are in a process, like economic, budget, time and business strategy constraints. By considering the elements described above, the output of the activity or process is obtained and that could be used as input of the following activity.

The figure below shows the scheme of the first activity of a NPD process, using the IDEF0 method, for a firm involved in the apparel manufacturing as a third party provider.

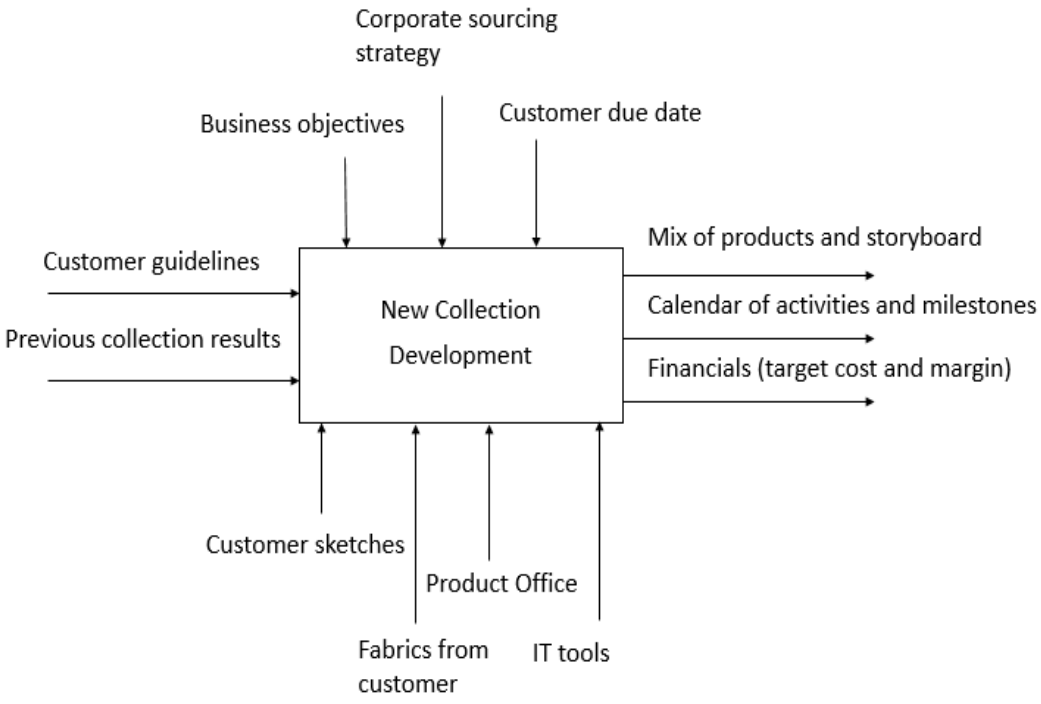

Figure 7. *Planning process description.*

The process of a new collection development begins when the company receives the order from the customer. A set of guidelines is provided by the customer and together with data of past collections, they represent the input (left side of figure). Company owns several systems to support the execution of process activities and resources and actors involved in the

organizational functions. For example, the sketches and fabrics provided by the customer, people working in the product department and software to manage the creation of the order (bottom side of figure). Company must take in consideration some external constraints, such as customer due date for the order delivery, and internal constraints, such as corporate sourcing strategy to match its business objectives (upper side of figure). The combination of input, resources and constraints lead to the output of the activity, the storyboard with products to create, the calendar for the planning of tasks and some preliminary financial information on target cost and margin (right side of figure).

After defining a clear scheme of the NPD process, a preliminary set of data should be formalized in order to share and discuss inside a Focus Group. Focus group is a market research method that brings together six to ten people in a room to provide feedback regarding a product, service, concept, or marketing campaign, while a trained moderator leads approximately one-hour discussion within the group which is designed to gather helpful information. In other cases, the focus group is not done for marketing purpose but to investigate the organization, detect problems and extract user needs that will be used for future considerations.

The users' needs collected in the focus group are then distributed and formalized through an AHP strategy. An AHP provides a well-defined methodology for decision-making problems to select the best solution on quantitative basis. In this case, the information extracted from the group discussion is reorganized in formal sentences that clarify a common point of view of users.

Subsequently, a QFD matrix can be built in order to link users' needs with functionalities expected in the software solution. Furthermore, by assigning weighs to each component and calculating the ranking, it is possible to define which PLM functionalities have the priority and must be present in the desired solution. Finally, the obtained results are useful to find the best software solution in the market that fits the needs of the firm.

The software introduction should be supported even by a change management strategy. Since the solution will be used by internal users, it is necessary to guide people through the change, by offering a complete roadmap of the required capabilities and changing tasks recommended to improve the work performance.

3.2.2 Implementation of PLM

Once the enterprise has selected the vendor solution to adopt, it moves on the implementation phase. A PLM implementation usually takes some time and its deployment is not so quickly.

The main reason for long implementation is mainly because the solution must be aligned with the enterprise needs, both in the case of a customised or a commercial package. Therefore, it is necessary to map processes to guarantee that the solution covers all business functionalities and do not spend too much time working in inefficiencies. The closer the new PLM overlays to the existing ways of working, the better the adoption and thus ROI is going to be. However, it is not advisable to work on existing functionalities that are not optimal and try to replicate them on the new system. It is recalled that the new system will do things in a different way.

Following, costs and difficulties related to new software introduction are detailed.

There are three main costs to consider:

1. Implementation. There is not a fixed time, but it depends on the complexity of the system and many other factors, such as type of solution. For example, the on-premise and SaaS solutions have distinct character. A SaaS solution could be implemented in few months and offers a cloud solution or a single-suite provider whose ecosystem is already deeply embedded in. On the contrary, on-premise PLM can take even years to implement, as reported in [17].
2. Hardware. If a company opts for an on-premise solution, it has to consider the cost of the actual server to build and maintain, and not only the software costs.
3. Integration. As described before, when an established firm changes its management system and goes through PLM, it has the necessity to integrate with existing applications, for instance by building the connection between PLM and ERP and import all previous databases. Expert people are essential in guiding the data migration and running the process.

Another aspect to consider is that PLM should not be considered only for engineering environment. According to [18], about 70% of PLM users come from outside engineering. This means that the tool should be understandable to anyone working in the company, from the procurement department, sales, marketing to operators working on the manufacturing floor. The PLM should provide user-friendly interfaces, in which flows are visible and intuitive, and give an user experience that allows system visibility, error correction and the right nomenclature.

The simplest is, the better will be the usage from user side, shortening the transition phase to the new system.

Once the tool has the proper configurations and interfaces, and all data migration has been completed, the following step is to give access to users. Unfortunately, this operation is neglected and the company often gives access only to some particular users. The idea is to give access to data only to users who are involved in that specific part of the process, perhaps to the exponents of that department or to people who interact with the tools and feed IT systems. However, the objective of PLM is the sharing of product data across the firm. If the sharing is blocked on some sides, the function of the tool is lost. Therefore, a company can gain greater value by releasing product data to employees who have little or no access yet, even if it seems that those people do not need the availability of that information.

An alternative way could be to give overall access to product data but put some constraints on the system, such as authorization. This allows to only specific groups of users to change data and give approval for activities, but it guarantees to all the visibility on the system. However, it is always necessary to consider the limits of the licensing agreement, in case the software is a standard program, which is designed and developed for the general user, and not especially designed according to customer's needs. In that case, the usage license agreement could limit both the number of allowed reproductions of the program or the number of machines in which the software can be installed and used, which is why the firm is forced to restrict data access.

Chapter 4

4. Change Management

The introduction of the PLM and the corresponding strategy to follow is not an easy procedure. A PLM initiative results in many changes inside the organization and surely people do not easily accept and understand changes. In order to promote change, a company needs to identify and implement actions to help change take place. An action plan should include the launch of a PLM initiative, the development of a PLM strategy and, finally, the deployment of PLM.

Change is difficult, time-consuming and costly, as we read on the book [19] . It is not sufficient to introduce a new tool or develop a new application, but it is necessary to understand the best way to exploit them. It includes defining what exactly the tool does and what its functionalities are and help users understanding how to use it and explain how the procedure will bring benefits to them. Therefore, a company should create an environment that promotes the change through communication, continuous improvement, leadership, learning and a proper reward system for its employees.

The actual organizational impact of PLM systems therefore depends on the fit between PLM and employees' tasks and on how managers have designed, sponsored and supported the use of the technology [20]. Many often we forget the central role that people play inside an organization. A company could have the best technologies and equipment, own the last updated software and be extremely innovation-based, but behind this, there will be always the people using them. Hence the need to prepare employees for the change and train them to acquire the skills to use the new tools.

Sometimes this does not happen. Firms do not invest in training because it is costly and time-consuming, since it subtracts working time to the organization. It is required an expert that guides the firm towards the change, maybe external to the firm, and also much involvement of the management. Particularly, managers and high-level employees should be the first ones to push the change and suggest new practices to all levels of the organization.

To ensure that employees adopt the new procedures, they must be informed about it. This means communicating the objectives and the strategy, providing them with support materials and be able to answer their questions. It is also important to define the actual status of the system and

how it could be after the implementation. In this manner, people can understand the reasons of the change and the expected scenario in which the organization wants to be.

In order to have a successful deployment of a PLM system, the company should put the proper efforts to build an organizational change management strategy, focused on eight success factors, as described in [21]:

1. Establishing a sense of urgency
2. Creating the guiding coalition
3. Developing a vision and strategy
4. Communicating the change vision
5. Empowering broad-based action
6. Generating short-term wins
7. Consolidating gains and producing more change
8. Anchoring new approaches in the cultures.

Since the introduction of the PLM requires a change strategy, the latter can be of two types: incremental or transformational [19]. In the incremental strategy, the change is introduced gradually and results from continuous improvement. For example, it can be applied on a single project and then extended to all the business or it starts as an initiative in a single department or function and then it applies at large scale. In the transformational strategy, the change is introduced all at once. It involves a rethinking and redesigning of the current process and the introduction of a new system that radically changes the way of working.

Once a new system is properly introduced in the firm, it is necessary to keep monitoring the environment in order to assess benefits and further implement the system. If a firm does not measure its performances, it does not have knowledge of the status of the system and related issues. After some time from the introduction of the PLM, it is necessary an assessment model that highlights the progress reached with the new system and existing issues that have not been solved yet.

A firm has many instruments to evaluate its organization; one of them could be the collection of its employees' feedbacks. In fact, they could provide useful insights on process and phases of the product lifecycle. Through their experience, they could remark some aspects that are not evident from the system analysis and from data collection. Indeed, it is a direct approach and is

subjected to individual opinions. Another way for performance measurement is data analysis. By collecting data and building specific indicators, a company can assess if it has reached its goals and requirements.

4.1 Change management in Pattern S.p.A.

As mentioned above, there is incremental and transformational approach to change. Pattern S.p.A. has decided to adopt the incremental approach to introduce the PLM inside the firm.

PLM concept was introduced in 2017 for the first time. The launch of the initiative was accompanied by a course addressed to almost twenty people. It was an introductive course about definition and functionalities of the PLM, not a training course. At the beginning, PLM has been considered as an innovative project on a trial basis. The first application was to fulfil an order from a client. Subsequently, it has been extended to the whole enterprise and adopted from multiple departments as a practice, although with a little resistance from some users. This approach allows the system to adapt slowly and does not upset the balance between environment and resources. However, the acquisition of the new system is not fully consolidated and still has some weaknesses.

From the investigations done, it seems that the PLM is consolidated and used in the first part of the process, for all development activities up to the marker-making phase. Then, it apparently stops to being used, probably because the following activities are mostly performed with the ERP.

The figure below shows an overview of the project management tool, *PM*, with the list of activities to carry out for the prototyping phase.

Fase	Attività	Totale giorni/fase	Totale giorni/prodotto	Gruppo utenti
01	1-Inizio Prodotto	35	3	
01	1-Creazione Scheda Prodotto	40	3	PRODOTTO MU
01	1-Modellatura	40	3	MODELLI UOM
01	1-Lancio	40	3	PRODOTTO MU
01	1-Piazzamento	40	2	CAD PIAZZAME
01	1-Taglio	40	2	TAGLIO
01	1-Preparazione Commessa	40	2	MAGAZZINO
01	1-Invio al Confezionista	40	1	SPEDIZIONI
01	1-Rientro da Confezionista	40	1	SPEDIZIONI
01	1-Spedizione Cliente	50	1	PRODOTTO MU
01	1-Approvazione	50	10	PRODOTTO MU
02	2-Completare Info Prodotto	45	3	PRODOTTO MU

Figure 8. *Collection planning, Pattern S.p.A.*

Employees uses the tool to upload information from the client, as the sketches, and create the product tab. After that, they use the CAD tool to make the pattern pieces. Then, with the CAD files, they can make the launch to obtain the withdrawals of materials and go on with the marker making, which gives the textile consumption and specifications for the cutting phase. It is evident that all the part related to the management of the warehouse is done on the ERP software. Cutting phase needs to be supported by the warehouse for the material provisioning and tracked on the ERP and also the activities related to the creation of the order, shipping to suppliers for the sewing and final delivery to client.

Employees stop tracking the progress on the PLM and rely only on ERP. In some sense, this inevitably causes the interruption of the workflow.

The role of PLM should be to push product data into the ERP and to pull financial data from it. They are complementary in some sense and not mutually exclusive. Actually, the main function of PLM is to share product data throughout the network for all stakeholders. It fuels collaboration and makes product development faster, easier, and cheaper. Therefore, while PLM contains the data on product components, giving information on the specifications such as measures and fabrics of a model, it is the ERP that actually pays for those components and manages financial information and procurement, referring the costs of components according to quantity and working cycles. In conclusion, both are needed to deliver a product to market.

Workflow

The workflow represents a key element of the PLM because it allows to visualize the current state of the process with information of the activities completed or to be started. The reason why it is so important is because the processes inside an organization are not so linear and are represented by many steps which overlap each other, hence the necessity to map the workflow through a diagram that allows to see the dependencies and constraints between activities.

Sometimes, the PLM workflow operates in a certain way and the business operates in another way. In fact, it occurs a divergence between the activities mapped on the tool and those performed in reality. In order to overcome difficulties, some users start to develop workarounds to perform their task and deliver the outcome. Workarounds fail to achieve governance standards and rely on manual processes to move projects forward. Here a concrete example of what happens in Pattern S.p.A.

What is missing is the workflow usage from some groups of users. The workflow is quite used during prototyping and sampling phase, but in the production stage it is less used. Perhaps, the

reason is that not everyone perceives the value of workflow. For example, from some feedbacks collected, it was found that employees working in the supply chain do not use the PLM to record the information about order shipments. They do not understand why they should put on the PLM this information since the latter is already present and visible on the ERP. They think it is not necessary to record the same information. Certainly, the duplication of information is not an activity that generates value but, in this specific case, the information could be meaningful for other actors involved in the process. For instance, the information is important for those users who wants to see the process at high-level and look at the process in general, like managers. In this case, they might immediately see if that activity has been completed or is delayed. Or else, employees from other departments who does not have visibility on the ERP may be aware of the progress of the activity from the PLM and continue with their activities without needing to wait for directions on how to proceed. Oral communication between departments is slower, due to the fact that work groups are located in different areas of the firm. It is no longer sustainable in a medium-sized company, which is why it needs to be standardised with a tool that records progress and effectively reaches end-users.

Hence the need for greater integration between the three main instruments for product development. If the procedure is automated, employees do not have to update manually the operations. The following two figures show how the current scenario is and how it should be in a perfectly integrated environment.

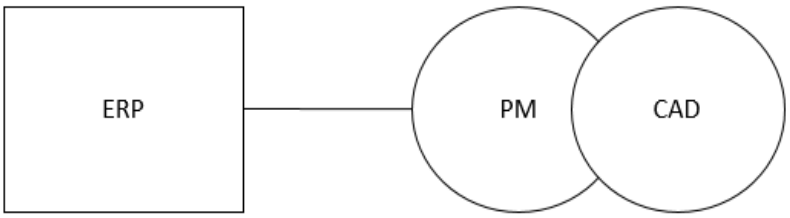

Figure 9. *Current integration between tools.*

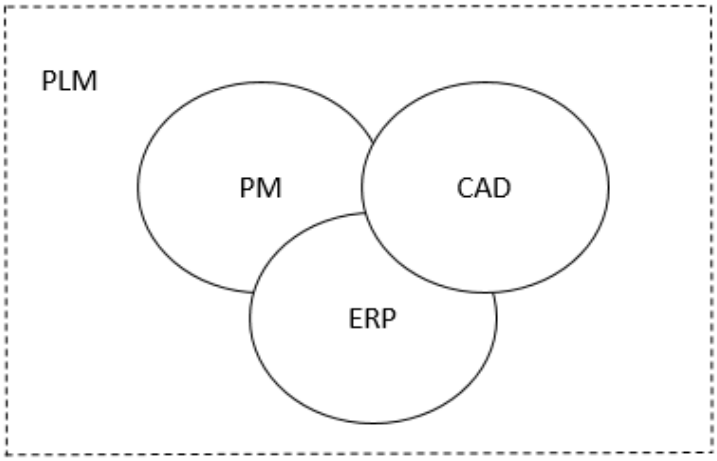

Figure 10. *Desired integration between tools.*

The first figure represents the current environment: CAD is strongly integrated with the project management tool, while ERP constitutes a separate block. All the CAD documents are easily imported and can be extrapolated from the PM, with the possibility to see the pattern pieces directly from PM. If a modification occurs on the CAD file or a new version is created, all the files connected to that product are grouped under the same section in the PM. This allows users to always work with the right document and do not make mistakes. Despite the strong integration between the two tools, they are not well integrated with the ERP and so they almost represent two separate environments. Employees make more manual operations to import data from a system to another and some information are recorded only in one of the two, so the user has not a complete view of the process.

The second figure shows the ideal environment in which the PM, CAD and ERP are perfectly integrated modules of the same system, the PLM. In that case, all information is available on the modules without the need to manual upload data or status of the activities. By improving the integration between design and production phases, the quality of the final product improves too because it owns the right specifications and is delivered on time. From the firm point of view, this assures the continuity of the business processes and a better view of the system.

Many IT companies are trying to build such kind of system that offers clear advantages, but it not an easy task since it does not exist a tool that fits all the organizations. Each enterprise has its own processes and practices, manage resources and activities in different ways. Therefore, manufacturing companies are forced to choose among existing commercial software, with poor performance results, or opt for a customization, usually more expensive.

Furthermore, to ensure full integration, it is not enough having a proper IT tool, but the firm should have an optimal strategy to grant the correct application inside the organization. The strategy depends on the core business and dimension of the firm, while the integration requires a deep analysis of process and data and a strategy that considers multiple solutions, people and resources.

4.1.1 PLM assessment method in Pattern S.p.A.

The scope of the following work is to make an objective evaluation of the current state of the PLM, after some years from the introduction, according to a defined approach that helps highlighting its use, its benefits, its weaknesses, together with different aspects of the organization. In details, the work is focused on the understanding of the PLM, what is its value, how it is used internally and the impact that it has on processes, resources and the whole organization.

The following diagram summarizes the concepts dealt with in the work.

EVALUAND	STAKEHOLDERS	PURPOSE	BENEFIT
• Process • Resources • Technological tools • Organization	• Company • Management • Employees	• Detect existing problems and criticalities • Give insight on current performance • Give guidelines to improve	• Supply chain (partners, suppliers) • Clients • Company

Table 1. *Identification of concepts for the analysis.*

Evaluand

The subjects chosen for the analysis are the process, intended as a sequence of activities leading to the realisation of the product, the resources, intended as all human capital and divided according to department of belonging, the technological tools, as the group of software which refer to the PLM and are used for the management of the product life cycle and lastly, the overall organization, intended as an entity and assessed according to its policy and strategic behaviour.

Stakeholders

The main stakeholder interested in the analysis is the company itself, because its objective is to understand the impact on the organization after the introduction of the tool. Therefore, it can make an investment evaluation and verify if there is organisational alignment with the new strategy. The other stakeholder is the management, which is interested in more detailed analysis from an operational point of view. Its objective is to understand all benefits and issues and possibly obtains some measurable indicators. Finally, there are employees, who are downstream stakeholders and use the tool in everyday activities. They expected to know the right way to use the tool to obtain the best performance.

Purpose

The purpose of the analysis is essentially to bring benefits to stakeholders. Through a deep analysis of the process, resources and means, it will be possible to detect existing problems and criticalities, if they exist and where they are localized. The investigation will bring some qualitative and quantitative data, suggesting insights on current performances. Lastly, with collected data, it would be possible to give a guideline, with corrective actions and activities to implement in order to improve individual task and overall performance.

Benefit

The benefit will be in primis for the company but, once the PLM strategy is correctly applied, there might be advantages for external entities too. In fact, clients experience shorter development times and order delivery on time, improved communication and more flexibility from the company side to react in customers' requests. As concerning partners and suppliers, they can receive more detailed information about production phase and better coordination for the managing of activities at a distance.

The process has been treated previously, in paragraph 2.2, with a detailed description of each activities and dependencies from the beginning, when input data are received from customers, going through development until final production. This allows to have an overview of the process also for external person who does not have knowledge of the system. Of course, it is company-specific and reflects how Pattern S.p.A. organizes its activities. The documentation of the process has been based on the following source [22].

The resources have been briefly described in paragraph 2.2.1 and during the process description, to highlight roles and responsibilities. Following, a recap is presented.

Human resources inside the company can be divided in five macro groups according to the job performed: product office, pattern office, CAD, cutting, warehouse and shipping office.

The product office is in charge of customer relationship management. It receives the orders and documentation from the customers and insert input data in the system. They monitor the whole process at high level to ensure compliance with customers' needs.

The pattern office receives the customers' sketches from the product office and tries to shape the idea of designers to create patterns. They create the model and product tabs with information on the type of garment, textile, colour, style, technical specifications of the fabric, like height, weft and prints and information about working cycles.

The CAD office receives as input all the previous information and insert them as parameters to design the CAD pieces with related measures. They use PGS CAD, a specific CAD tool for fashion manufacturing. Once the patterns pieces are created, they make the optimal placement of the patterns inside the fabric, by finding the material consumption and specification for the cutting process with the tool Marka.

The cutting department uses the files created with the marker making, the cutting sheets, together with the materials received from the warehouse. For manual cutting, placement is done directly on the fabric, using cardboard models or paper printed by a plotter. Their job is to prepare cut fabrics to send to external laboratories for the final trimming and sewing of the garment.

The warehouse takes care of the management of the items. After the launch done by the product office, it receives the list of material withdrawal and prepares the orders to send to the cutting department or external suppliers.

The shipping office is responsible of tracking the flows of orders that arrive at the warehouse or are shipped to customers or suppliers, reporting the information on the ERP tool.

As concerning technological tools, software particularly, they were treated in paragraph 2.3. In order to have an overview of the IT coverage on different areas, a scheme is reported below.

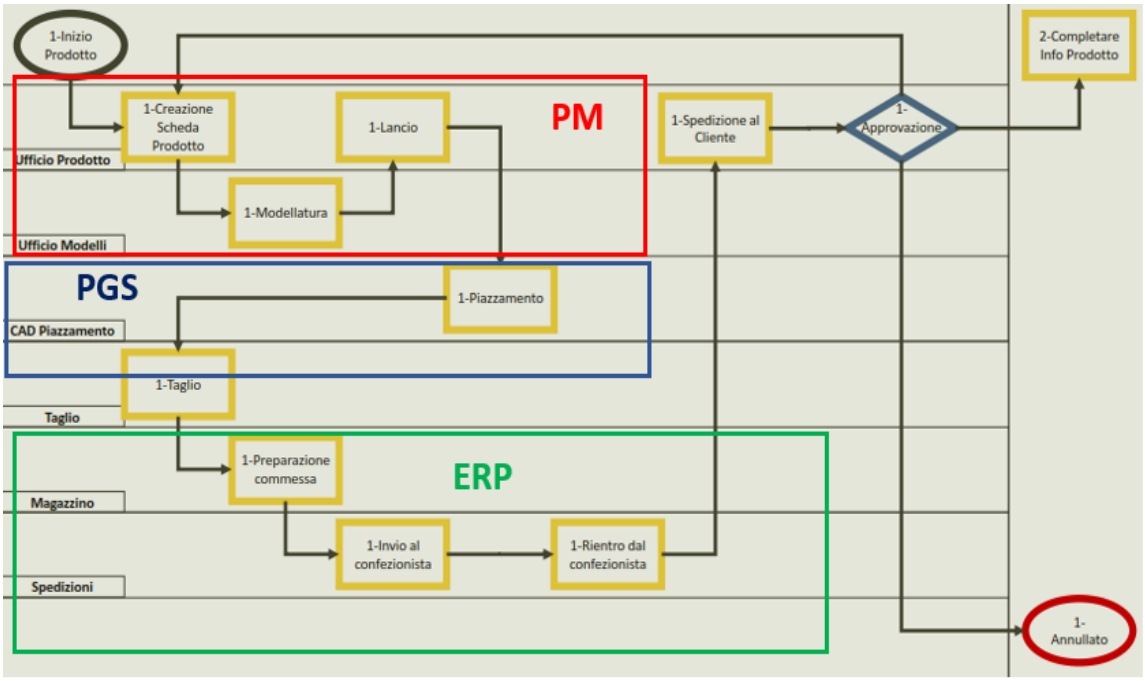

Figure 11. *Workflow in Pattern S.p.A.* [22]

The figure shows the workflow for a product with all the activities through which it passes and that need to be performed to complete the product. On the left side, it is shown the groups of users that are on charge of the activity. Furthermore, there are clusters by type of tool used to perform the task, which highlight the IT coverage in the various activities, helping to visualize by whom and for what the software is used.

4.1.2 Empirical assessment

To empirically validate the PLM framework of Pattern S.p.A., a structured questionnaire was built and addressed to specific persons working inside the firm. This enables to determine the PLM maturity of an organisation, based on users' feedbacks. The selection of the method was oriented to individual interviews rather than a quantitative questionnaire addressed to all employees, because this could lead to misleading information and rigidity from user side. Differently, the identified method aims to obtain more reliable information, by asking the right questions to the right people and putting the person at ease as if it were a standard conversation and not an evaluation.

The questionnaire is built by referring to [23] and structured in many questions that cover five areas of interest:

1) Strategy and policy.
2) Monitoring and control

3) Organisation and processes
4) People and culture
5) Information technology.

The questions within each business dimension try to bring out what the critical points and the actual usage of the tool, the opinions of users and the approach they have to the system and many other characteristics based on user perception and experience.

These are shown below in Table 1.

Strategy and Policy	**Monitoring and Control**	**Organisation and Processes**	**People and Culture**	**Information technology**
PLM introduction: When the company decided to introduce the PLM, did it explain the strategy and related changes, what was the use of the new instrument and why it was introduced? How was it explained and by whom?	**Responsibility and allocation of work:** How are tasks and activities divided among employees? Is there a job allocation per department or are there subdivisions within members of the same team/department? Is this internal subdivision formalised?	**Support for the PLM:** Are there any PLM support procedures? Are they applied/updated? Are they formally written? If you need help/explanation about the system, who do you contact?	**Understanding the system:** Do you really understand what PLM means? Are you familiar with the use of the tool? Do you have a good knowledge of the instrument or do you think that training or courses are needed to deepen the use of the instrument?	**Functionality and traceability:** Do you think the software in use is suitable for the type of company? Does it cover all the functionalities required by the industry? Which ones are not covered yet? Does it allow you to track all the information you want? How does it increase collaboration between teams?
Organisational alignment: Is the PLM strategy in line with the company strategy? Was it adapted to the context and needs of the company? Was	**Product control and monitoring**: Do the company define internal standards on product delivery time or is the deadline always dictated	**Activity Management:** Are the activities carried out within the product life cycle standard or are they linked to the type of product/case? For example, if an unexpected event occurs, do	**Expectations and post evaluation:** What were your expectations for the PLM? What benefits did you expect and what benefits did you get? What advantages you did not get and	**Document Management:** How do you consider document management and related product/collection files? Is the management of different product

there a particular need for which it was decided to introduce the PLM? What was the scope?	by the customer? Who is in charge of monitoring the product progress? For example, if an activity is ready to be started, is there an alert from the system, from the manager or employees are autonomous in deciding when to start the activity?	employees perform a standard procedure to bring the activity into line or is the situation analysed and decisions taken on the type of event basis?	you would expected? (For example, reduction of waiting time to receive information, reduction of product development time, improvement in activity management)	configurations easy? How is the documentation organized? Compare with the situation prior to the PLM introduction.
Organisational alignment: Did the company present an action plan for the PLM introduction? Describe the deployment. Did it monitor the trend during time span? How do you define the current maturity level of system? (use not yet consolidated, use quite defined, level of maturity reached)		**Workflow:** Does the PLM guide the product release process? For example, when you have to switch to the following activity, does the PLM determine whether you can do the next activity or other type of instructions are expected? Are the employees guided by the PLM or do they communicate with each other about the activities to carry out?	**Usage:** Do you use the instrument daily or only if necessary? What are the main activities in which it is considered fundamental and which ones where it is not used? Why? For example, when you complete a task, do you immediately report information on the system or do you perform it later? Do you mark the start/end dates of the activity?	**System integration:** Do you think that the current system is well integrated? Whi ch part of the system is less integrated with the others? Where are the critical points in which you cannot find a connection to other systems? Do you think that the tool has helped you improving your productivity or does it represent a double effort?

Table 2. *Questionnaire.*

Under each business category, the questions are divided in subtopics that help identifying the specific area to address. Furthermore, some questions are addressed only to a certain category of people and not to all interviewees, depending on the role occupied by the person in the organization.

In addition, the questionnaire is based on the principle of validity, trying to properly measures all issues from the PLM context, of reliability, by correctly posing the questions and finally it aims to have a practical application, considering the type of the work and the type of user involved. In fact, the investigation is done on quality basis rather than quantity, by taking a small sample of employees that represent the key users of the PLM and who know well how the process works.

This assessment model aims at analysing and drawing some conclusions on two overall aspects in particular: the PLM maturity and the business-IT alignment. The first one refers to the different growth stages that can be identified for the PLM and allows to state at with maturity level is the PLM inside the company, for instance, if its use is not well structured, if it is quite defined but not consolidated yet or if it is optimal and has reached a good level of maturity. Instead, the second one, the business-IT alignment, is based on the idea that PLM technologies should fit to the organisation. In this case, the system is evaluated under the strategical point of view to see if the level of technology and innovation is in line with the type of business and satisfies users' needs and expectations.

User definition

The questionnaire has been addressed to nine persons, each one working in a different department with various roles. People that participated to the interviews have different background and experience, in fact, some of them have been working for several years and have seen the evolution of the company over time, while others have recently arrived. This contributes to have a variety of points of view and a greater contribution to the understanding of people's perception of the system.

The six covered departments have been the product office, pattern office, CAD office, procurement, production, supply chain.

Product office

The product office is the group that has been most impacted by the introduction of PM. Its work is almost performed on this tool that helps reporting the information from customers' orders.

The department is organized in small teams, each of them take care of its own client. Behind this, there's another subdivision inside the team, in fact, there is a person who follows the prototyping and sampling phase and another for the production phase. This represents a strategical decision made by the company to assign the work according to the type of customer and specific phase of the process. In details, the choice is to have a person who is in direct contact with the customer, receives all the indications and is involved in product development, follows the customer from the beginning and leaves him at the time of acceptance of the production. Once all requirements are satisfied for the sampling, the information are passed to another person who is in charge of the production and works on the management and optimization of time and deliveries. Due to the transfer of knowledge, it is necessary to have a good alignment between the employees who work in different stages of the process but have the same customer's order to manage.

The main tool used by the office is the PM which allows to insert information about a product, such as materials and measurement, and to make the codification of items. Once the product is ready, the launch is performed in Gamma, the ERP. This operation allows to transfer the information about the product and obtain the material consumption and indications for the warehouse. The main problem detected is that the transfer of data from one system to the other is not immediate and employees have to wait in order to see the updated information on the ERP. At the beginning when the system was introduced, it was necessary to wait about one hour for the passage of data from PM to Gamma, now it has been reduced to 15 minutes. Anyway, it represents a weakness of the system that has not been corrected yet and a problem for employees, especially in high productive days, because they have to suspend the activity and wait some time before going on. If a code modification needs to be done because of a mistake or a change in the item, the approach that was adopted to overcome the problem is to modify the code directly from the ERP without make the previous change in PM and wait for the updating.

For the production phase, there is a complete transition from PM to Gamma. It would require too much efforts to change the parameters one by one on PM and then wait for the updating. This is the reason why PM is used mostly in prototyping and sampling stages, where it has to deal with a single product and make the modification on it, while in production, where there are an increasing number of products, it is better to manage high volumes through ERP.

Despite some criticalities, the system shows good potential and allows to record all necessary information and use them for future retrieval. If the user correctly feeds all the fields in the product sheet, the system is able to support the user in following stages and give complete information. The incompleteness of information is another issue which is due both to human error and system flaws. For example, a problem related to the procurement is that sometimes materials are not available, but they are necessary to make the launch, the material list to take from the warehouse and send to the suppliers. The system has to track this information which should be a trigger for other departments to take corrective actions. If the information is missing, operators have to do a double check to fix the problem and communicate the right information, often requiring a manual work and increasing the effort.

In addition, for a system to be efficient, it must subject to maintenance periodically. If the system reveals low or no maintenance, it will contain errors made in the past that are still present. In this sense, the system appears rigid because there is no possibility to cancel the performed actions.

Over the years, users have been actively involved in the process of improving the system and this proves their willingness to be supported by the technology. Some initiatives have been done to promote the automatization and to substitute manual tasks, in order to avoid activities that do not create values and to speed the process as much as possible.

Users results to be independent in carrying out the activity and leading the process. They rely on the use of the system to retrieve and trace information, but they act independently for most of the time. This shows that it is not the system which guides the process, but the tools are considered just as instruments of support. The scheduling of the work is not dictated by the system, which only provides deadlines based on order deliveries, but it is the individual who manages its time and schedules the activities. Due to the characteristic of the sector, the system is subjected to rapid changes and need to be responsive. If an unforeseen event happens, employees are committed to reorganize the work and bring the activity on time. So, it does not exist a standard procedure to follow but it needs to investigate the problem on a case by case basis to find the solution.

The communication can be analyzed considering external and internal relationships. The product office maintains a direct channel with customers and communicates with them in several ways, such as e-mails, conference call, meetings and so on. There is no a standard communication mode also because the information is continuously exchanged, and the

customers require to be assisted during all the product development. It is fundamental the exchange of documents because they are used as input for the activities.

For the development phase, PM seems to be a complete tool because it enables to insert the detailed characteristics of the product, such as the bill of materials, the codification of models and the materials, the working cycles and, in addition, it can record dates about the delivery of fabrics, orders delivery and all the finish dates of internal activities, such as the CAD patterns creation, the marker making and the cutting.

By inserting the information of the completion of the task, people can see from the tool that the activity is concluded, and they can move on with the following activity. However, the progress of the activity is not always marked. Due to the limited time available or common habit, it is easier for employees to exchange the information by voice or e-mails instead of entering the data into the system and waiting for the other department to see the updating. Therefore, a functionality exists on the tool, but it is not well exploited by users who prefer to guide the progress of the phases in alternative ways.

This could have a negative impact on the traceability of the product because the information is not registered in the tool, the history and the progress of the product is lost and users cannot have knowledge of what happened. The system lacks in performance if it is not well alimented but at the same time shows flaws on the software side. According to its structure, the tool does not allow to get all the information necessary to understand where the product is and why it is blocked on a specific activity, so there is the need to integrate with other forms of communication between teams. Following these considerations, the workflow, which should be an essential instrument in the management of product lifecycle, looses its function and it is not of particular meaning for the employees, which do not obtain great information from it.

Pattern office

The pattern office was the one that assisted to the major changes due to the introduction of technology. In the past, their work was completely manually and with the adoption of new tools, they experienced the change with the complete transition from the analogue to the digital. The switch to another working methodology was implemented gradually. Initially, employees have started to insert the parameters of patterns inside the software with the help of manuals. Then over the years, many training courses have been done to help people improving the knowledge of the IT tools, after new software releases.

However, due to the nature of the sector, manual work cannot be excluded because there is the need to see the physical realization of the garment to understand the general yield, while the software is seen as an instrument to simplify and speed up the work.

It exists a close relationship between the pattern office and the product office, because the product office works directly with the clients and receives the information that will be communicated to the pattern office. In particular, the product office interacts with the customer to establish the type of materials, fabrics, accessories and, once defined, it communicates them to the pattern office, who deals with the technical part such as the garment structure and the fit. Due to this strict relationship, the assignment of job is the same as the product office and employees are divided in small teams, each one working for a specific client and with the correspondent team of the product office.

The only tool used is PM, where all information concerned the materials and product categories must be recorded. Here the importance to track and store the information, useful for future retrieval. The current tool is aligned with the needs of business and allows to create and link documents without overwriting previous files. For instance, when a prototype is subjected to substantial changes after a client's inspection, a new document, linked to the previous one, is created.

As concerning the workflow, it is a fundamental tool that helps to identifying the product and understand in which stage of the process the product is. Unfortunately, the contained information is not always true because the system is not feed properly, or data are not available promptly because are inserted later. In addition, the tool does not show the position of the product inside the production cycle. In fact, it is possible to check the status of the single activity, but the overall status of the process is missing. Moreover, the tool allows to see the individual product, but it is not possible to track multiple products at the same time, confirming the statement that, due to its configuration, the instrument is mostly used in prototype stages and not for production. Nevertheless, the user reports that over the years information have improved, because the system has entered more into everyday usage and become almost automatic.

Users are autonomously in leading the process and the software represents a system in which reporting the information. A large part of the information does not pass through the system and is exchanged by voice, in the e-mails or is lost in the course of the activities. For instance, the system does not contain specific functionalities for the tracking of unexpected events and does

not automatically prompt users to take new actions. Therefore, users are responsible for the control and management of contingencies, which are quite common in the environment. They only record the information about particular events with no possibility to manage them optimally.

CAD office

The CAD office creates the CAD patterns and size development and performs the marker making.

When the concept of PLM was firstly introduced in the firm, employees expected a greater impact with the adoption of new tools, for instance the possibility to track all the information, insert all the patterns with the relative progress status, less e-mails and printed documents and more automatization in the process. At the beginning, everything was inserted into the software, but over time the use of the system decreased, while some old procedures have been restored.

In order to start their activities, the CAD office needs to receive the confirmation to proceed from the product and the pattern offices, which unlock the activity or the product. If the information is not reported in the software, they have no visibility and do not know when it is possible to start the activity. Often, it is not possible to be guided by the system because the information is not present and comes from different channels. In the software, the process has been designed with a sequence of activities assigned to different teams. If the procedure is not properly followed and some steps are performed independently from the system, employees receive requests from other departments, but they cannot see the activity on the tool. This could lead to the interruption of the working flow jointly with an unstructured communication. However, the system is not sufficiently structured to allow groups to advance work autonomously, but a communication between the departments is always necessary.

Unlike the other two departments described above, the tasks assigned to the employees are divided by type of function and not by client: some of them perform the size development while others do the marker-making. So, the CAD office receives all the requests from product office with all the customers' orders and it is not divided in subgroups that manage only the order of the assigned customer. In the software, the functionality for the scheduling of jobs is not well implemented, therefore for the employees is difficult to manage orders manually and assign a priority according to scattered and incomplete information which comes from other channels. On PM, it exists a field to insert the priority of the activity but is not used, consequently the user only sees a list of tasks to do without priority and is forced to ask or decide alone which

ones to advance. Even if there is an expected delivery date, the tool does not take in consideration the other constraints for the delivery of the order and so it is not reliable. To overcome the problem, users have recovered a procedure applied before the introduction of the software. They use excel files that contain the list of jobs with the priorities assigned manually, not according to the system but prioritized according to the needs of the individual. This represents a disadvantage for the department because they have to open multiple files and assign priorities, generating confusion in the work progress.

Procurement office

The role of the department is to process the information regarding materials and accessories, establishing the purchasing quantity and sending the orders to suppliers.

Users reported that the information received by other departments do not come in a standard form and are not formalized, on the contrary they arrive in a differentiated way depending on people, with emails or other type of documents. In order to properly track and standardize the flow, the information should pass through the system, which needs to allow the compilation of equal fields, avoiding incomplete information or errors. The information should be visible to everyone in the tool and cannot be exchange only between two entities, as happen between the product and the procurement office. In the PLM approach, everyone can access to the system and find the desired information in the same repository. Employees' needs to have a more automated process have led to a proposal. It consists of standardizing the data flow through the use of an existing module on the ERP, the MRP, in which all product features are added, and it automatically provides what materials are necessary and when.

The main tool used for the procurement is the ERP. Data on material consumption are directly provided by the product office, who derives them from PM. They also have access to PM, but it is mainly used to check or retrieve any missing information, in case received information are incomplete. The other task performed in PM is the costs insertion. The double use of two different software does not facilitate the work. In fact, the items codification is done on PM and the costs are managed in the ERP. Data must flow between the two and, as said before, the passage of information is not immediate, the user has to wait some time to see the updating on the other tool.

As for the CAD office, employees need to do the procurement for all types of orders that come from customers. The orders are generated according to the material demand for type of product or collection. In general, the procurement should issue orders related to two type of items in

particular: for items that are specific of a product, for example a particular fabric or a zip, the order must be placed according to the consumption of that product, for items that are general and present in different products, such as inner linings of a garment, the order should not take as input the consumption of the single product but merge consumptions of multiple products, giving the possibility to issue a single order covering monthly requirements. Currently, even the purchasing orders for common materials are done for the single product because the tool is not able to combine data from different collections and customers and is not able to generate a demand forecasting. A weakness of the software is that it only shows a point estimate of consumption of the single garment and not of the whole production, preventing to optimize orders. By making a deeper analysis, the system actually allows it, but it is not fed enough to provide correct data after some extractions.

The current tools do not have strong reporting capabilities and the possibilities to aggregate data and make queries are few. Database contains a lot of data, but beyond few extractions created ad-hoc, there is no possibility to decide how to aggregate data. As a result, the procurement office issues the orders on the basis of users' requests and cannot anticipate the orders only based on information contained in the system.

Production office

The department takes care of the production orders by setting parameters and adding information to generate production sheets. The main tool used is the ERP, but with the introduction of PM, user has found itself with more functions to perform.

The main activity carried out in PM is to fill out the bill of materials. This sheet must generate the material withdrawal list from the warehouse, so it is necessary to export it in the ERP. As said before, the updating and transfer of data to the ERP is not immediate and the user has to wait before to see them. The PM has all the product information but fails to automatically make the sheet, which has to be made by hand by the operator. The problem is that the system is not able to combine internal development information with client's information about the product, due to different codification. The missing automatization in the generation of the production sheet is time consuming and it costs about half of a working day equal to the time of compiling a sheet, depending on the complexity of the product.

However, it has been reached a good level of the production management, considering that before the introduction of the tools the information about the progress of the collection such as

number and type of garments, were manually reported in excel files and shared between different departments, with no updating in real time.

Also in this department, the allocation of job is for type of customer, therefore a person follows the production orders of his customers and obtains the information from the correspondent team of the product office that manages the same customer order in the prototyping and sampling phases. This subdivision is dictated by the fact that each customer has different needs, from the generation of labelling, packaging, documents, shipping and approval methods. Therefore, as the company has not identified a standard procedure to manage the product development cycle, it has decided to adopt a specific modality to follow the client closely by providing highly specialized people with a deep experience and knowledge of the client.

As concerning the management of work and priorities for the production stage, employees drive the activities and set milestones according to the delivery date of the customers, and are autonomous in deciding which are the priorities according to the type of customer and related deliveries, it is not the system that calculates the due dates according to capacity and internal requirements.

Supply chain office

The department mainly works on the ERP, being the only instrument for the materials handling and the creation of documents for the transport. The use of PM is very limited because it only reports the dates of development phases, while the supply chain is interested to see the physical movement of objects, for example when fabrics need to be shipped to external laboratories or when the prototype is sent to the customer or when materials are delivered to the warehouse.

However, it would be necessary to include the information of certain deliveries and concluded activities also on PM because they are not automatically reported in the system and they could be useful to other users to understand the progress of the activities and a better visibility of the process status. It exists a sort of resistance from users because they do not understand the advantage of reporting manually some information on PM that already exist in Gamma, where the dates are automatically generated with the creation of the transport documents. This concept is enforced by the thinking that on PM the dates are reported manually and so they are subjected to human error, while on Gamma they are reliable because they depend on the issuing date of the document. The working phases are imported from PM and with the date details generated by the documents, the department has a real-time mapping of where the products are in Gamma.

To overcome the problem of a double system in which tracking the information, a proposal suggested by users is to reverse the flow. Since the material handling is managed with the ERP with reliable information, the flow should go from ERP to PM with an automatism that updates the progress and dates of the activities.

The PM tool is not particularly useful for the employees and they do no use it daily. In some occasions, they use it as a support to extract some detailed information. This remarks the concept that the PM is a good option to manage the first part of the product cycle, the development, while the production is managed differently. In fact, the advantage of using Gamma is that users have visibility on the whole mix of collections and products, while in PM only of the single product.

4.1.3 Results

Following the results of the questionnaire, some considerations are needed in order to synthesize the main points of attention and possibly give suggestions for further improving.

- The organization is divided in departments according to the function but the internal divisions inside the teams are not homogeneous. In fact, in some departments, the work is assigned according to the type of customer and each subgroup manages the orders of that customer. This happens for the product, pattern and production office. On the contrary, other departments receive all general requests from other departments and they have to carry out the activities independently from the type of customer order, as happens for the procurement, CAD and supply chain office. The allocation of job for type of customer is dictated by the fact that each customer has different needs and the process of new product development is highly customized, therefore the firm has decided to adopt a specific strategy to follow the client closely by providing highly specialized people. However, such choice has a different impact on other departments, as it generates complications in the management of the activities and allocation of priorities and the system is not able to classify the activities or to aggregate data to optimize the process. A more standardize approach in the management of the product development and flexible roles could be necessary to sustain a company that is rapidly growing.
- A problem has been highlighted and shared by many departments. It is about the data flows between the two main systems, PM and Gamma. In fact, the transfer of data is not immediate, and employees have to wait in order to see the updated information. If a

code modification occurs, it would require too much efforts to change the parameters one by one on PM and then wait for the updating. This is the reason why PM is used mostly in prototyping and sampling stages, where it has to deal with a single product and make the modification on it, while in production, where there is an increasing number of products, it is better to manage high volumes through ERP. This represents a weakness of the system and, although the waiting time has been reduced over the years, it has not been completely removed and represents a problem for employees, especially in high productive days.

- Users recognize the importance of feeding the systems with consistent data in order to have complete information to use when needed. However, the incompleteness of some fields, which is due both to human error and system flaws, is frequent, in particular the finish dates of activities are not always reported into the system. Following, it is presented the tendency for type of activity.

ACTIVITY	% OF NON-COMPILED FIELDS
Unlock of the model for the CAD development	27%
Launch	35%
Marker-making	23%
Cutting	36%
Shipment to external supplier	37%
Delivery to customer	47%

Table 3. *Percentage of non-compiled fields for type of activity.*

The field indicates the finish date of the activity that should be included in PM by user in order to close the activity and allows other users to start the following phase. The table shows the percentage of non-compiled fields for type of activity, obtained from a sample of 1950 models, excluding the values of incorrect dates. The delivery date to customer is the one that is reported less with 47%, followed by shipment and cutting, perhaps because users use the ERP to manage the last part of the process and do not see the advantage to report also on the PM. The activity in which the date is most often filled in is the marker-making with 23%, perhaps because it is necessary for the cutting department and it marks the finish of the development phase. Therefore, a functionality exists on the tool to mark the progress of the activity, but it is not well exploited by users, due to the limited time available or common practice. However, even with complete information, the system does not have capability to guide alone the users and to act as a trigger, by suggesting actions to take.

- Users results to be independent in carrying out the activity and leading the process. They rely on the use of the system to record and trace information, but they act independently for most of the time. This shows that it is not the system which guides the process, but the tools are considered just as instruments of support. The current tools are quite aligned with the needs of business, enabling to track and store data with a good document management, useful for future retrieval. However, the system has been designed years ago and over the years the needs are constantly changing, this is why the system appears rigid in some aspects. Most information does not pass through the system and is exchanged in other channels and the system does not contain specific functionalities for the management of unexpected events, causing inevitably that people become responsible for the process and apply different solutions to manage the events.
- As said above, the process was designed years ago as a sequence of activities that, in some cases, could no longer be appropriate for the product cycle. There is no possibility to model the life cycle and creates a specific cycle for a product, but the activities must adapt to the current system and sometimes the process does not reflect the real needs. If it is not possible to include specific details, some information is missing and this could have a negative impact on the traceability of the product, the procedure is not properly followed and some steps are performed independently from the system, causing the interruption of the workflow. The latter, which should be an essential instrument in the management of product lifecycle, looses its function and it is not of particular meaning for the employees, which do not obtain great information from it. In addition, the actual workflow does not have strong capabilities. In fact, it does not show the position of the product inside the cycle. It is possible to check the status of the single activity, but the overall status of the cycle is missing. Moreover, the tool allows to see the individual product, but it is not possible to track multiple products at the same time, confirming the statement that, due to its configuration, the instrument is mostly used in prototype stages and not for production.
- Due to the assignment of work inside department, there is a misalignment between departments that works for function and departments that work for type of customer. This leads to some difficulties in the assignation of priority and scheduling of work. For instance, the CAD office receives all the requests of the models to develop without a priority. On PM, the functionality for the scheduling of jobs is not well implemented, consequently the user only sees a list of tasks to do without priority and is forced to ask or decide alone which ones to advance. Even if there is an expected delivery date, the

tool does not take in consideration the other constraints for the delivery of the order and so it is not reliable.

- The issue described above, together with others related with management of the activities, could lead to the recovery of old procedures used before the introduction of the new system. For instance, excel files that contain the list of jobs with the priorities assigned manually, not according to the system but prioritized according to the needs of the individual. This approach could be risky because it creates a divergency with the current system. It would be better to take advantage of the solutions present in the software and try to improve those functionalities so that all the information flows into the system.
- Another problem detected is the standardization of data flow that comes to some departments, particularly in the procurement office. Information does not come in a standard form and from the same channel and therefore is not formalized. This implies the impossibility to optimize orders and make demand forecasting, but the orders are done case by case. Even if the type of business is characterized by a higher variety of items subjected to customization, it would be advisable to optimize costs on common materials, providing access to desired information in a single repository.
- In addition, for a system to be efficient, it must subject to maintenance periodically. If the system reveals low or no maintenance, it will contain errors made in the past that are still present. In this sense, the system appears rigid because there is no possibility to cancel the performed actions.
- Over the years, users have been actively involved in the process of improving the system and this proves their willingness to be supported by the technology. Some initiatives have been done to promote the automatization and to substitute manual tasks, in order to avoid activities that do not create values and to speed the process as much as possible.
- The results obtained could be used to evaluate in broad terms the two mentioned aspects, the PLM maturity and the business-IT alignment. The first one is evaluated according to the following reference model (Table 3).

Maturity model	*Features*
Unstructured	The PLM topic has been recognized and its importance agreed. Work must be done to define and develop the PLM concept and standards. However, at present, there are no defined approaches concerning lifecycle management; all lifecycle and product management issues are resolved by individuals on a case-by-case basis.
Repeatable but intuitive	Lifecycle and product management processes have developed to the stage where similar procedures are followed by different people undertaking the same task within one organization. There is no formal development, definition, training, or communication of standard processes; all responsibility is left to individuals. There is a high degree of reliance on individual knowledge and therefore errors occur.
Defined	Processes and basic concepts are standardized, defined, documented and communicated through manuals, training. However, the human factor is important, there is no end-to-end PLM process supporting IT system, all work is completely or partially manual from the process point of view. IT systems support individual parts of processes. The PLM process or basic PLM concepts are not best-of-the-breed, nor are they uniform throughout the corporation, however they are formalized. There is common understanding of the to-be model how PLM shall be executed in the future.
Managed and measurable	It is possible to monitor and measure the compliance between processes and to take action where processes are not functioning well. Processes and concepts are under constant improvement and provide best practices. IT systems support PLM processes well. Process automation is used in a partial or limited way. Processes and concepts are developed through clear vision throughout the corporation. The state of uniformity of processes is clear.
Optimal	Processes and concepts have been refined to the level of best practice, based in continuous improvement and benchmarking with other organizations. IT is used in an integrated manner and process automation exists on an end-to-end basis.

Table 4. *PLM Maturity Model.* [24]

The maturity level reached inside the company could be likened to the "*repeatable but intuitive*" level but also to the "*defined*" level. In fact, activities are carried out with similar procedures, but not completely standardized and there is high degree of reliance on individual knowledge. Nevertheless, IT systems support most of the process and there is common understanding of PLM concepts and the to-be model. As regards the business-IT alignment, the current technologies have been designed to fit the specific process and they still cover a good part of the business needs. However, the system suffers from the first signs of downgrading because users' needs are continuously changing, and maintenance is required. It is important to keep monitoring the status of the system and introduce the right level of innovation, especially for a growing company, in order to improve the competitiveness and the overall business performance.

5. Conclusion

The research presented in this thesis has had as its objective the exploration of the PLM, from a conceptual but also applicative point of view. Here, the main topics dealt with are summarized, trying to provide a starting point for future works.

The first part is purely theoretical and provides an initial understanding of the PLM concept. PLM was born as a strategic approach to manage the development process for those sectors that face complex projects and many criticalities in the overall productive process. Later, this working strategy has been adopted even in more traditional sectors because it helps facing difficulties in today's challenging market. In particular, the fashion industry is facing reduced time for the product development and launch in the market and increased number of collections produced during the year, achievable only through excellent resource management and coordination.

Then, it has been treated a specific case study, the Italian company Pattern S.p.A. which operating in luxury fashion engineering. Born as a small business, it is now a growing company that represents a landmark for most prestigious luxury fashion brands worldwide, providing engineering and manufacturing services. A detailed study of its process and assets has been performed to understand the current system and build the basis for a possible assessment.

In addition, a PLM study cannot be dissociated from its practical and technological aspect. The adoption of PLM must be accompanied by the right instruments that allow to integrate systems and by the proper methodologies that establish collaborative work inside the organization. This does not necessarily mean that a company must switch to a new information system, but it should make a careful analysis of its infrastructure and evaluate its needs. After that, it can proceed in selecting the software that fit better its requirements. Following a market review, it can be noted that there is no turnkey software solution that provides all the functionalities expected of a PLM system for the apparel industry. Consequently, the IT tools have to be selected after the analysis of business and users' needs.

The last part of the work is focused on the evaluation of the impact that the PLM tools have on the company in examination. After some years from the introduction of new instruments, it has been described the approach used by the firm referring to the change management and methods of a PLM implementation. An assessment method has been built to identify the process, resources, benefit and problems of the current system. It mainly relies on interviews with

representatives of the software's end-users who gave greater contribution to the understanding of the system.

By analysing the results obtained, shortcomings in the current system have emerged due to a lack of automation, maintenance, user involvement and degree of innovation. The current system was born for the management of the product, in particular for the development part and it is not configured as a real PLM that should manage the whole life cycle of the product. In any case, users have a clear vision of the PLM approach and are actively committed to improve the system. From here, it seems that the system is still aligned to the business needs and provides a valid support in the running of the activities. Remembering that, in this specific enterprise, the product development process is subjected to high customization and it is extremely difficult to treat orders in the same way. However, it is advisable to standardize more the activities, communication and data flows into the systems with the common objective to have the process as smooth as possible. This will allow to face issues in the best way, be on time and deliver high quality products to customers by staying ahead of the market.

Appendix

PLM - *Product Lifecycle Management*

ICT - *Information and Communication Technologies*

PD - *Product Development*

MES - *Manufacturing Engineering Systems*

ERP - *Enterprise Resource Planning*

CAD - *Computer-Aided Design*

IT - *Information Technology*

CRM - *Customer Relationship Management*

BOM - *Bill of Materials*

PDM - *Product Data Management*

CDM - *Collaborative Demand Management*

CPDM - *Collaborative Product Development and Management*

NPD - *New Product Development*

IDEF0 - *Integration Definition for Function Modeling*

AHP - *Analytic Hierarchy Process*

QFD - *Quality Function Deployment*

ROI - *Return on Investment*

SAAS - *Software as a Service*

R&D - *Research and Development*

CAM - *Computer-Aided Manufacturing*

CAE - *Computer-Aided Engineering*

CIM - *Computer Integrated Manufacturing*

MRP - *Manufacturing Resource Planning*

KPI - *Key Performance Indicator*

MTO - *Make-to-Order*

References

[1] M. A. J. M. Enrico Vezzetti, «Supporting product development in the textile industry through the use of a product lifecycle management approach: a preliminary set of guidelines,» 2015.

[2] The Business of Fashion and McKinsey & Company, «The state of fashion,» 2019.

[3] «https://www.statista.com/outlook/244/100/fashion/worldwide,» [Online].

[4] L. Firth, «The true cost,» [Online]. Available: https://truecostmovie.com/learn-more/environmental-impact/.

[5] J.-M. B. ,. V. Olivier Abtan, «Rethinking the fashion supply chain,» [Online]. Available: https://www.bcg.com/it-it/publications/2013/retail-supply-chain-management-fast-flexible-lean-rethinking-fashion-supply-chain.aspx.

[6] «Impact Of Globalization On Fashion And Pharmaceutical Industries Economics Essay,» November 2018. [Online]. Available: https://www.ukessays.com/essays/economics/impact-of-globalization-on-fashion-and-pharmaceutical-industries-economics-essay.php.

[7] S. M. J. S. Elizabeth Hunter. [Online]. Available: https://www.mckinsey.com/industries/retail/our-insights/the-need-for-speed-capturing-todays-fashion-consumer.

[8] G. Gulberti, January 2018. [Online]. Available: https://www.launchmetrics.com/resources/blog/fashion-industry-supply-chain.

[9] Accenture strategy and Fashion for good, «The future of circular fashion: "Assessing the Viability of Circular Business Models",» 2019.

[10] Pattern S.p.A., «Investor presentation,» September 2019. [Online].

[11] «The Pattern Souk,» [Online]. Available: https://www.patternsouk.com/marker-making-auto-nesting-cut-planing-services/.

[12] D. B. J.-P. L. M. B. Konstantas, Interoperability of Enterprise Software and Applications, Springer-Verlag London, 2006.

[13] «K2innovation,» [Online]. Available: . (http://www.k2innovation.it/cose-il-plm-2/).

[14] A. I. Antti Sääksvuori, Product Lifecycle Management, Springer, 2005.

[15] I. S. S. T. S. Howard R. Moskowitz, An Integrated Approach to New Food Product Development, CRC Press, 2009.

[16] M. A. &. B. M. Enrico Vezzetti, «New product development (NPD) of ‘family business' dealing in the luxury industry: evaluating maturity stage for implementing a PLM solution,» *International Journal of Fashion Design, Technology and Education,* 2016.

[17] N. Fleming, «The Forrester Wave™: Product Lifecycle Management for discrete manufacturers,» November 2017. [Online]. Available: https://investor.ptc.com/static-files/8bdcc9c8-f8d7-4b24-9917-ef98af632f10.

[18] «Upchain,» [Online]. Available: https://www.upchain.com/blog/what-to-look-for-in-a-plm/.

[19] J. Stark, Product Lifecycle Management: 21st Century Paradigm for Product Realisation, Springer-Verlag London, 2011.

[20] F. M. a. P. N. Marco Cantamessa, «Understanding the organizational impact of PLM systems: evidence from an aerospace company,» 2010.

[21] J. Kotter, «Leading change,» *Harvard Business School Press,* 1996.

[22] Vittorio Serino, Pattern S.p.A., *Processo di sviluppo di una nuova collezione.*

[23] H. R. a. V. J. Batenburg R., «PLM roadmap: stepwise PLM implementation based on the concepts of maturity and alignment,» *Int. J. Product Lifecycle Management,* 2006.

[24] A. I. A. Saaksvuori, Product Lifecycle Management, Springer, 2008.