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SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Cloud Manufacturing as a competitive opportunity for artisans: a case study in the Italian footwear industry

TESI DI LAUREA MAGISTRALE IN
MANAGEMENT ENGINEERING - INGEGNERIA GESTIONALE

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Academic Year:	2020-21

1. Abstract

Cloud Manufacturing has emerged as a service-oriented paradigm that has the potential to revolutionize manufacturing processes. Its deployment addresses all industries where there is a need to rationalize, standardize, simplify and accelerate manufacturing processes, from planning to post-sales. Cloud Manufacturing realizes the power of Cloud Computing, allowing manufacturers to be more flexible than ever before. Companies can leverage on the capacity of multiple parallel manufacturing facilities and manage an entire product catalog through a single control platform. The potential brought by Cloud Manufacturing is promising to the extent that it could shape the business model of the future. There is a growing interest in this field in the academic world and, so far, most of the publications are seeking to define the structure and properties of this new paradigm. However, there is a lack of studies in the existing literature aimed at exploring an actual implementation of the model. Therefore, this research aims to provide the starting point for a concrete adoption of Cloud Manufacturing. The Italian footwear industry, deeply rooted in the tradition of artisan production and affected by a crisis mainly due to the poor level both of technological development and digital innovation, emerged as the perfect candidate for the model implementation. The research examines the possibilities offered by Cloud Manufacturing, of revitalizing the various small and less structured manufacturers, providing them with a business model capable of increasing their national demand and recognition in international markets. The method followed consisted in conducting interviews with several industry experts, which led to the discovery of "Italian Artisan": an Italian start-up that has moved the first steps towards the creation of a platform based on the Cloud Manufacturing model. A case study of their business model was conducted, aiming at highlighting critical points and opportunities for improvement. Findings from the case study suggest potential areas for improvement and many gaps in terms of opportunities that Cloud Manufacturing can deliver. In the final part of the work, an idea for a new business model is proposed, based on the concept of "District Cloud Manufacturing" that encompasses all the insights achieved throughout the research.

Keywords: Cloud Manufacturing, Italian Footwear Industry, Italian Artisan

2. Abstract in lingua italiana

Il Cloud Manufacturing è emerso come un paradigma orientato ai servizi che ha il potenziale per rivoluzionare i processi di produzione. La sua diffusione si rivolge a tutti i settori in cui c'è la necessità di razionalizzare, standardizzare, semplificare e accelerare i processi di produzione, dalla pianificazione al post-vendita. Il Cloud Manufacturing si avvale della potenza del Cloud Computing, permettendo ai produttori di essere più flessibili che mai. Le aziende possono sfruttare la capacità di più impianti di produzione paralleli e gestire un intero catalogo di prodotti attraverso un'unica piattaforma di controllo. Le mutevoli condizioni di produzione possono essere monitorate in tempo reale e possono essere compensate passando facilmente a fabbriche di maggiore capacità o qualità. Il potenziale portato dal Cloud Manufacturing è promettente nella misura in cui potrebbe definire il business model del futuro. C'è un crescente interesse in questo campo nel mondo accademico e, finora, la maggior parte delle pubblicazioni cercano di definire la struttura e le proprietà di questo nuovo paradigma. Tuttavia, c'è una mancanza di studi nella letteratura esistente volti ad esplorare un'effettiva implementazione del modello. Pertanto, questa ricerca mira a fornire il punto di partenza per una concreta adozione del Cloud Manufacturing. Il settore calzaturiero italiano, profondamente radicato nella tradizione della produzione artigianale e colpito da una crisi dovuta principalmente allo scarso livello sia di sviluppo tecnologico che di innovazione digitale, è emerso come il candidato perfetto per l'implementazione del modello. La ricerca esamina le possibilità offerte dal Cloud Manufacturing, per rivitalizzare i vari piccoli e meno strutturati produttori, fornendo loro un modello di business in grado di aumentare la loro domanda nazionale e il riconoscimento sui mercati internazionali. Il metodo seguito è consistito nel condurre interviste con diversi esperti del settore, che ha portato alla scoperta di "Italian Artisan": una start-up italiana che ha mosso i primi passi verso la creazione di una piattaforma basata sul modello di business Cloud Manufacturing. È emerso quindi un caso di studio sul loro business volto a evidenziare i punti critici e le opportunità di miglioramento. I risultati del caso studio suggeriscono potenziali aree di miglioramento e molte lacune in termini di opportunità che il Cloud Manufacturing può offrire. Nella parte conclusiva del lavoro, viene proposta un'idea di modello di business, basato sul concetto di "District Cloud Manufacturing" che racchiude le intuizioni ottenute durante l'intera ricerca.

Parole chiave: Cloud Manufacturing, Settore Calzaturiero Italiano, Italian Artisan.

3. Executive Summary

The industrial sector has been shaped overtime by a sequence of major technological innovations. These disruptive innovations lead to changes in the production processes and had strong impacts in production capacity of companies, eventually creating conditions for new business models. Internet of Things (IoT) and Cloud are two main technologies enabled by Industry 4.0 that have driven the shift toward new business models rooted in the concept of "Servitization". Cloud Computing is revolutionizing industries and enterprises as dynamically scalable and virtualized resources are delivered as a service over the Internet. Cloud Manufacturing (CM) is the implementation of manufacturing-as-a-service paradigm into a Cloud Base System. With the emergence of Cloud Computing, CM has become a promising manufacturing paradigm that will drive companies towards new manufacturing business models, leveraging on common elements such as networked manufacturing, ubiquitous access, multi-tenancy and virtualization, big data and the IoT, everything-as-a-service, scalability and resource pooling.

To acquire knowledge on real cases implementation, two companies working as Cloud Manufacturing platforms are analysed: Xometry and Protolabs; both can be considered as on-demand industrial parts marketplaces providing custom and serial parts. The clients of those platforms provide technical drawings and precise specifications of the items that they need to be produced, usually using CAD models. The platform, then, analyses the proposed projects providing real-time pricing and manufacturing feedback. The main difference between the two cases is that while Xometry operates only as a marketplace, relying on a network of external supplier to manufacture the customized products, Protolabs owns in-house machinery that allows it to keep the production process within the boundaries of the Company.

The research lays its foundation in the significant gap that has emerged between the literature on the Cloud Manufacturing paradigm and actual case studies, aiming to provide a case study of a CM platform implementation. The Italian footwear industry, made up of a large number of artisanal companies which has been severely impacted by "big, structured brands", is the ideal candidate for the purpose of this research. The ultimate goal is to determine whether it is possible to implement the model of Cloud Manufacturing in the Italian luxury footwear industry, characterized by a complex supply chain and by a final product made up of at least thirty components. The purpose is to restore the industry by interfacing artisans with international markets to create new business opportunities exploiting the benefits offered by the paradigm.

The Italian footwear industry is characterized by a production process that involves several actors and is based on historical relationships among consolidated territorial structures (districts). For this reason, the main source of valuable insight was derived from interviews conducted with industry experts, entrepreneurs, managers, artisans and designers. The key experience that made it possible to get in touch with several different realities was the participation to two of the most important fairs of the sector, both hosted in the halls of "Rho Fiera Milano" in September 2021. “MICAM” Milan, promoted by Assocalzaturifici, is the world's leading footwear exhibition. It is a unique appointment of its kind: the reference point for operators from all over the world; “Simac Tanning Tech” is the international appointment with the most qualified offer of machineries and technologies for the footwear.

After a critical analysis of the interviews, an appropriate level of understanding over the Industry has been reached. Italy is the leading shoe manufacturing country in the European Union, it holds the eighth place among world-wide footwear manufacturing countries in terms of volumes exported, but the third place in terms of value; comprehends about 4,100 companies and an overall annual turnover that in 2019, was around 14.3 billion euros. In Italy the industry is characterised by a number of artisanal manufacturers that have to bear huge labour costs, since a considerable part of the production process for luxury shoes is carried out by hand by highly experienced craftsman. In the last twenty years, the Italian footwear system has undergone a strong downsizing in terms of employees, companies and production volumes. The number of companies in the national industry dropped by 42,85% from 2000 to 2019 (pre-covid), while the production volumes experienced a fall of 54,01% in the same years. The causes can be found in the globalisation process, mainly started by the entry of China in the World Trade Organisation (WTO) in 2001 that have led the Italian industry to face new competitive economies from emerging countries and in the economic and financial crisis originated in 2008.

The national footwear industry, even if downsized in terms of production quotas, managed to rebuild its competitive advantages by increasingly shifting production towards the high range and towards higher value-added products, leveraging on its traditional strengths: the quality of the materials used and manufacturing techniques capable of combining traditional craftsmanship with modern production technologies. However, this path of transformation and restructuring had to face over the past year a new crisis linked to the spread of Covid-19, that in 2020 caused to the industry a lost about a quarter of its total turnover. In this scenario, the only companies that perform well in the luxury footwear industry are the major brand like Gucci, Hermès, Chanel, Louboutin and so on. While small and medium-sized companies are forced to navigate by sight, accepting increasingly reduced production orders. In the last decades a lot of companies in the industry decided to specialize and to keep under their control only some critical activities of the production process. A lot of small and medium artisanal shoe factories now only deal with the assembly phase of the product, outsourcing the production of components to trustworthy suppliers. As a consequence of this situation a decreasing number of companies is capable of dealing with the development and design phase of a model.

Today the sector is under the pressure of a demand that continues to require high quality but at the same time seeks an extreme customization in taste and style with non-standard shapes and finishes. Therefore, the evolution of demand imposes to the footwear system to develop a continuous process of technological innovation supporting the production process in order to introduce new materials, new shapes, new styles. This process would ensure high quality standards essential to maintain competitiveness in high-end products. The footwear production system, despite the presence of so many excellences in all its productive articulations, overall is still weak in terms of ability to activate innovation processes and investment choices. The investigation on innovation system during the interviews, registered a widespread delay in the adoption of innovative practices: the productive segment still relies on an intensive manual approach that still manages to satisfy demand. The new push factor that could accelerate the processes of transformation is undoubtedly represented from the possibility to approach the technological opportunities of industry 4.0 (supported from an extraordinary plan of incentives to the investments), developing productive models based on the paradigm of the intelligent factory.

The case of an innovative Italian start-up (Italian Artisan), that operates in the luxury footwear industry, is then reported. Since the Company seems to present the typical characteristics of a Cloud Manufacturing platform, the authors analysed in deep the services offered by the Start-up and its functioning in order to assess whether it can be considered the first example of a CM platform in this specific industry. Italian Artisan is a B2B marketplace that connects international brands, retailers and designers with authentic Italian artisans by providing online tools for the creation or customization of luxury shoes. The Platform offers two types of services: the customer can create a completely new "Private Label" project or can chose to customize an already existing product from the

“White Label” catalogue. Italian Artisan manages to offer manufacturing capabilities as cloud services to any user and plays a key role in managing and connecting manufacturers with customers, but in performing this task it employs considerable managerial effort. The platform does not support intelligent matching, but, basing on the input design and user requirements, it asks for suitable manufacturers to provide a quote for each request. This process differs from the literature that envisions a platform that can provide instant/fast quotations. The main challenge for Cloud Manufacturing implementation lies in coordinating the dense network of players involved within the supply chain. "Italian Artisan" to overcome this problem leaves the management of the supply chain to manufacturers. The platform, therefore, does not present all the fundamental characteristics of the cloud manufacturing paradigm. However, it adequately responds to the structural needs of the industry, proposing a system that fits the needs of the sector but fails to fully exploit the potential that Cloud Manufacturing can bring.

Since the services offered by Italian Artisan do not cover the entire supply chain of the industry, there is the possibility for the implementation of a new Cloud Manufacturing platform that facilitates the relationships between shoe manufacturers and component suppliers, which are critical especially in the prototyping phase. The new platform would connect companies planning to develop new model of shoes, with suppliers who offer components already produced in the past and ready to be used and modified for the creation of new prototypes. The idea originates by leveraging on a critical issue that emerged from the research about the industry and the case of Italian Artisan: one of the most significant costs for manufacturers resides in the new models’ development process. The prototyping phase is at the hearth of the process that leads to the production of a new model of shoe, therefore companies dedicate to this stage high resources in terms of time and costs.

In this context a Cloud Manufacturing system is proposed for manufacturing districts where, each actor in the supply chain would be able to provide production capacity for components already produced in the past. This would allow to amortize the development costs reusing the vast series of components preserved over the years. Moreover, by combining components in innovative ways, or modifying them a little, new shoe’s structures can be developed with a significantly lower use of resources. The potential of the model also lies in the possibility of reducing the time needed for prototyping. Basing on the interviews conducted with different realities that characterize the industry, the authors estimated that the introduction of the platform would lead to a reduction around 50% of the time needed for the development of the final prototype. In order to overcome difficulties related to the willingness to collaborate, the online community would be developed initially within the footwear districts. In these areas companies and suppliers know each other and have probably already cooperated in the past. In fact, for a company operating in the luxury footwear industry, it is essential to work with partners that can completely trust, since the maximum quality must always be guaranteed, and the production of the prototype must be completed in time for the release of the seasonal collection. This new Platform named "District Cloud Manufacturing" represents the starting point for future development, providing a reference base for effective experimentation.

4. Contents

5. Introduction

The Research is structured into seven main chapters. The Fifth chapter is dedicated to the literature workflow that has driven to the origin of Cloud Manufacturing, covering the stages in chronological order: from industry 4.0 through Cloud Computing to the Cloud Manufacturing paradigm. Chapter 6 discusses two cases of existing companies that base their business model on Cloud Manufacturing. Subsequently, having understood the dynamics that characterize this concept, Chapter 7 introduces the Research Questions, Purpose and Methodologies implemented. Following this, interviews are presented, which were conducted during visits to exhibitions, companies and a design school. The interviews were a crucial source to obtain valuable insights useful to build and develop the Research Project. Chapter 8 presents the study carried out on the complex Italian footwear industry. Essential for the research is to understand how the industry has evolved over the years, what are the most important trends, how the supply chain is organized and who are the actors that compose it as well as it is essential to understand the production process and timelines. Chapter 9 introduces the main theme of the research: the transformation towards the smart footwear factory and the industry 4.0 model. Chapter 10 is dedicated to the case study of an Italian start-up company that has moved the first steps in the realization of a Cloud Manufacturing project and that is now preparing to scale-up with the conclusion of its crowdfunding campaign. From the case study is made an analysis in comparison with the literature aimed at highlighting possible missed opportunities and criticalities of the model. Chapter 11, the final chapter of the research, presents a proposal for a CM platform that was conceived as a response to the results of the entire study, connecting interviews with experts, literature and findings on Italian Artisan.

6. Literature Review

In this chapter the authors analysed the existing literature related to the concept of Cloud Manufacturing (CM). The analysis starts from the study of the industrial revolutions that have laid the foundations for innovative technological trends that have revolutionized not only industry but also the modern society. After having introduced the main enabling technologies of industry 4.0, a focus has been made on the paradigm of Cloud Computing, the precursor of Cloud manufacturing. Ultimately, CM is analysed, by reviewing definitions, participants and architectures, concluding the literature with its opportunities and complexities.

6.1 Industry 4.0

6.1.1 Overview

The industrial sector has been shaped overtime by a sequence of major technological innovations. These disruptive innovations lead to changes in the production processes and had strong impacts in production capacity of companies, eventually creating conditions for new business models.

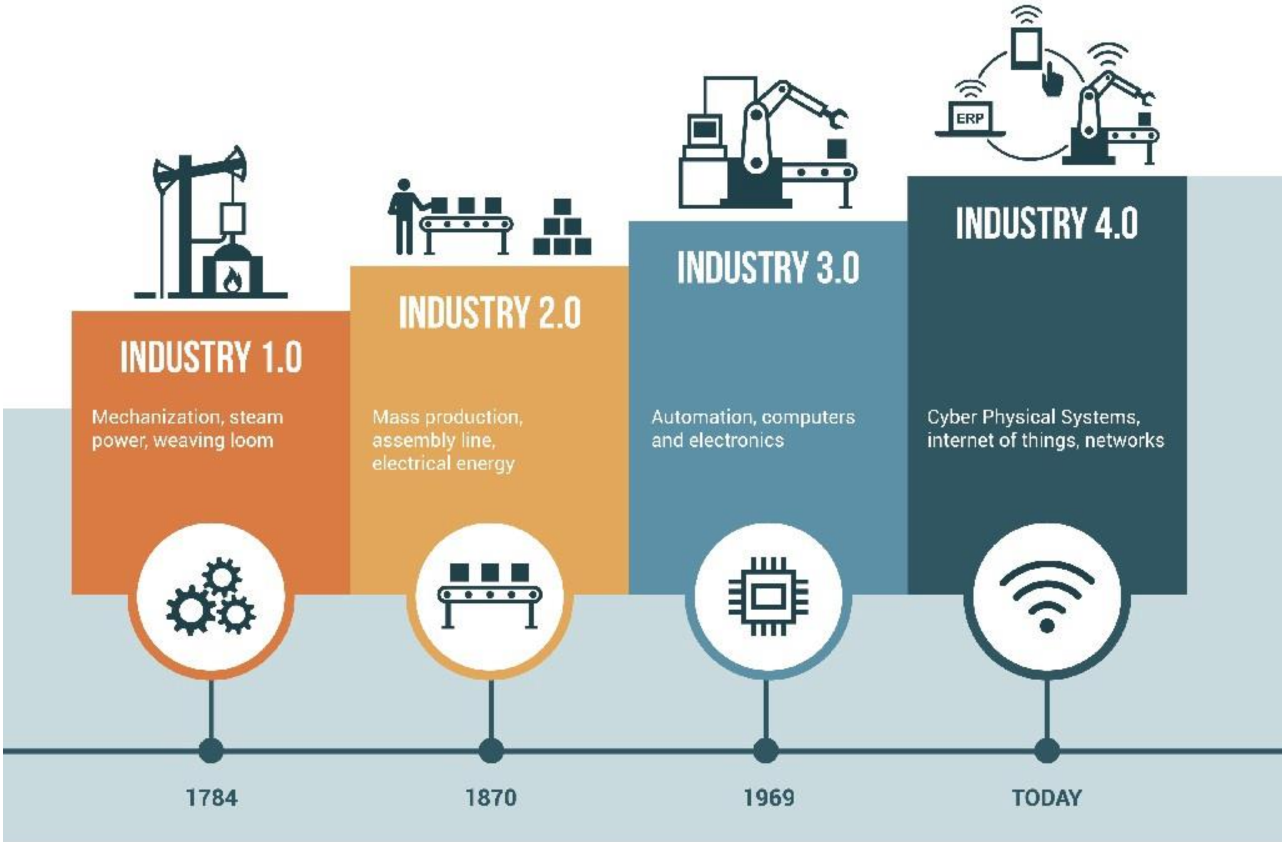

Figure 1: Time framework of industrial revolutions (1)

The starting point was the *First Industrial Revolution* in the 18th century, in which water and steam energy was harnessed for the mechanisation of industrial plants. The *Second industrial Revolution* was induced by the introduction of electricity and of mass production. This latter was possible thanks to the re-thinking of the production process, through the division of labour and the ideation of assembly lines. The *Third Industrial Revolution* took place in the 1970s, thanks to the automation of certain processes through the usage of electronics and computer power. The *Fourth Industrial Revolution* is still ongoing, and it is characterised by the application of digitization to manufacturing processes.

The latest revolution is associated with the term Industry 4.0, this concept was conceived in Germany in 2011 and its goal is the creation of smart factories. These factories are characterised by highly digitized manufacturing processes where information flows among machines in a controlled environment (J. Qin et al., 2016). (2)

The basis of Industry 4.0 is the Cyber-Physical Systems (CPS). They generally combine sensor networks with embedded computational capability to monitor and control the physical environment. The sensors are connected via Internet, following the paradigm of the Internet of Things (IoT).

Apart from IoT, the Boston Consulting Group (BCG) identifies other fundamental technologies that are required for a successful implementation of industry 4.0 transformation. These technologies are deepened in the following chapter of the research, and they are: Big Data and Analytics, Simulation, Virtual and Augmented Reality, Additive Manufacturing, Horizontal and Vertical System Integration, Autonomous Robots, Cybersecurity and Cloud Computing.

6.1.2 Enabling technologies

Internet of things

Gartner defines the concept of IoT as "the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment" (3). The system is based on the existence of intelligent objects, which acquire a counterpart in the digital world. They are capable of interact and communicate between them and process the amount of data collected.

In order to be defined as "smart objects" a device must have some compulsory properties related to the self-awareness: identifications, localisation and diagnostic. However, the smart objects could also present properties of interaction, such as metering (measure the consumption of resources), sensing (measuring signals from the environment) and the possibility of performing actions. Other possible properties are the capability to process and communicate.

The Industrial Internet of Things (I-IoT) is the application of IoT devices in factories, in order to support production processes and other aspects linked to operations. IoT devices can help in IdCoding material and WIPs to better monitor what happen inside the plant. They can also improve planning and scheduling activities. Moreover, smart devices are not only useful to increase efficiency, but they can also guarantee a higher level of safety in the working environment, monitoring material movements inside the factory and checking if the right components are used during manual activities.

Another important application of I-IoT devices is in maintenance. Through data collection related to time of usage, pieces produced and other similar parameters, it is possible to prevent or limit machine failures.

Big data and analytics

Big Data (BD) can be described as a huge amount of structured, semi-structured and unstructured data of different types, coming from interconnected heterogeneous objects. As a consequence of the fact that manufacturing companies started to adopt advanced information and knowledge technologies to facilitate their information flow, a huge amount of real-time data related to manufacturing started to be accumulated from multiple sources. BD can be characterised according to three dimensions (the "3Vs"): the *volume* of data, the *variety* of data types and sources, and the *velocity* at which data are processed. The volumes of BD are huge, but they do not have a reference quantity. The terms usually refer to data in the range of petabyte-exabyte. With respect to smaller amount of data, BD can reveal more patterns and interesting relationships. The simple storage of BD does not bring much value to companies, the core activity is the analysis that can be executed on them. To explore data, advanced data analysis is required, using techniques like Online Analytical Processing (OLAP) and Data Mining. OLAP supports multidimensional data analysis and allow users to obtain answers to ad hoc questions. On the other hand, Data Mining is more discovery-driven and provide insights into corporate data by finding hidden patterns and relationships in large databases and inferring rules from them to predict future behaviour (Laudon et al., 2020) (4)

Simulation

Simulation is defined as an imitation, over time, of a system or a real-world process. It is a way of dealing with the complexity of the systems with elements of uncertainty, that cannot be resolved with usual mathematical models. In the perspective of Industry simulation is a key technology for developing exploratory models to optimize decision making as well as the design and operations of complex and smart production systems. (Ferreira et al., 2020) (5)

Simulation allows experiments for the validation of products, processes or systems design and configuration. Simulation modelling helps on cost reduction, decrease development cycles and increase product quality.

Augmented Reality

The aim of Augmented Reality (AR) is to increase human performances, supplying the needed information to a given specific task. AR technology increase operator's perception of reality by making use of artificial information about the environment. The aim is achieved enhancing visualization by overlaying digital data and images onto a physical real-world environment.

In order to allow the users to visualize information, these AR devices use the following visual tools (Syberfeldt et al., 2017) (6):

- *Video*: merged worlds (real and virtual) into the same digital view;
- *Optical*: real world with virtual objects overlaid directly on the view;
- *Retinal*: direct projection of virtual objects onto the retina with the use of low-power laser light;
- *Hologram*: real world mix with virtual objects using a photometric emulsion;
- *Projection*: projection of virtual objects directly on real-world objects with the use of a digital projector.

Additive Manufacturing

Additive Manufacturing (AM) is a set of emerging technologies that produces three dimensional objects directly from digital models through an additive process, particularly by storing and joining the products with proper polymers, ceramics, or metals. In details, additive manufacturing is initiated by forming computer-aided design (CAD) and modelling a set of digital features of the product, those items are then submitted to industrial machines. The machines perform the transmitted descriptions by adding material layers. Raw materials can be in form of liquid, powder, or sheet and are especially comprised of plastics, other polymers, metals, or ceramics (Alcàcer et al, 2019) (7)

According to the standard of the International Organization for Standardization (ISO) processes are classified into seven categories (ISO/ASTM 52900:2015):

- *Binder jetting*: process in which a liquid bonding agent is selectively deposited to join powder materials.
- *Directed energy deposition*: process in which focused thermal energy is used to fuse materials by melting as they are being deposited.
- *Material extrusion*: process in which material is selectively dispensed through a nozzle or orifice.
- *Material jetting*: process in which droplets of build material are selectively deposited.
- *Powder bed fusion*: process in which thermal energy selectively fuses regions of a powder bed.
- *Sheet lamination*: process in which sheets of material are bonded to form a part.
- *Vat photopolymerization*: process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization.

Horizontal and Vertical Systems Integration

Engineering, production, marketing, suppliers, and supply chain operations, everything connected must create a collaborative scenario of systems integration, according to the information flow and considering the levels of automation.

The system integration can be seen from two viewpoints: *horizontal integration* and *vertical integration* (Suri et al.,2017). (8)

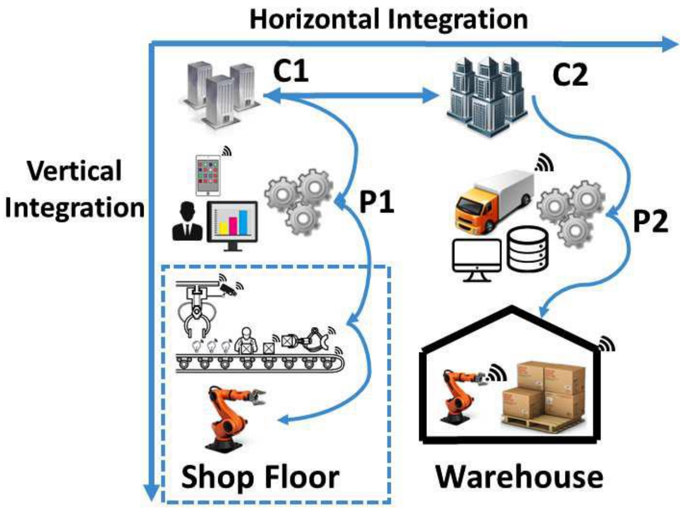

Figure 2: Representation of horizontal and vertical integration (Suri et al., 2017) (8)

The horizontal integration (or inter-company integration) can be considered the base for a strong collaboration between various companies and their stakeholders. The companies can interact with each other and create an inter-connected ecosystem. This will enable them to exchange data or information and avoid vendor lock-in issues.

Vertical integration (or intra-company integration) allows to improve the exchange of information and the collaboration among different levels of the enterprise's hierarchy. It enables real time data sharing and facilitates activities such as corporate planning or production scheduling. Vertical integration digitalizes all the process within entire organization, considering all data coming from manufacturing. This allows to have a better traceability of the processes and consequently a better impact analysis of the changes made in different layers.

Autonomous Robots

In the last years a general shift in manufacturing paradigm from mass production towards mass customization has taken place. The impact of this trend on production systems is that they should adapt to handle more product variation, smaller life cycles, and smaller batch sizes (Pedersen et al., 2016) (9). For this reason, reconfigurable automation technologies, such as robots, are becoming increasingly important.

Moreover, adaptive and flexible robots combined with the usage of artificial intelligence provide easier manufacturing of different products by recognizing the lower segments of each part. This allows to provide decreasing production costs, reducing production time and waiting time in operations (Salkin et al., 2017) (10).

In order to achieve complex manufacturing tasks, robots need to be capable of working together with other robots connected on a collaborative community, and to share the information gathered from their own work over this community. An example of this collaboration is presented by Wagner at a*l*. (2016) (11), their work describes the realization of a cooperative scanning approach by two industrial robot arms. The basic idea is the distribution of the movements on two robots by one robot handling the sensor and the other one handling the workpiece.

In smart factories robots not only can collaborate with other robots, but also with humans. However, they are not much capable of smoothly working together in the same working space because of safety issues.

In this situation additional flexibility is required, both for robotic arms and for mobile robots. In particular, the speed of the robot must be reduced, and the mechanical design must ensure that moving parts are not a danger to the user (Ben-Ari et al., 2017) (12).

Cybersecurity

In the era of industry 4.0 industrial systems are being interfaced with internet communication technologies to form the smart factories and manufacturing organizations of the future. However, existing Internet technologies are plagued by cybersecurity and data privacy issues that will present major challenges for adopters of Industry 4.0 technologies. If these challenges are not appropriately addressed, the true potential of Industry 4.0 may never be achieved (Thames and Scaefer, 2017) (13). For example, cyber-attacks on critical industrial equipment are able to undermine the business model of a company.

According to a study conducted in 2018 by Make Uk (14), formerly known as Engineering Employers' Federation (EEF), 48% of the interviewed manufacturers said that they have at some time been subject to a cyber-security incident, and half of them suffered some financial loss or disruption to business as a result.

To face this problem, several standards have been issued over the years suggesting various cybersecurity methodologies and techniques. The most popular among the standards for IT are the ISO/IEC 27001 on information security management systems, issued by the International Organization for Standardization (ISO), and the cybersecurity framework proposed by the National Institute of Standards and Technology (NIST) (15).

These standards suggest a structured approach to cybersecurity, promoting a clear definition of roles and responsibilities and the adoption of risk management practices. However, as reported by Culot et al. (2019) (16) in their study, managers receive just a limited support from these standards. In particular:

- Standards are perceived as too complex and bureaucratic, not oriented toward practical solutions.
- Technologies are evolving at unprecedent pace, making the reported practices rapidly obsolete.
- Implementation is resource- intensive and time-consuming.
- The adoption of standards is often cosmetic and not substantial, making it difficult to assess the level of cybersecurity of business partners basing on certifications.

Since its impossible to protect companies from all possible cyberattacks, risk management analyses are increasingly adopted, extended classic approaches to cyber risks

prioritization and mitigation. These approaches include the Failure Mode and Effect Analysis (FMEA) and the application of Risk Priority Number (RPN) to digital assets. Risk may also be prioritized using more quantitative analytical techniques including Monte Carlo Simulation, enabling the approximation and estimation of economic impact.
According to the study of Corallo et al. (2020) (17), the most critical assets in terms of cybersecurity in Industry 4.0 are Industrial Control Systems (ICS), followed by Industrial Internet of Things gateways, sensors and actuators.

Cloud Computing

Cloud Computing can be defined as the on-demand distribution of IT resources via the Internet. Companies can delegate the management of one or more IT resources to a specialised provider, these resources are then provided through an outsourcing contract. In this context the company does not have to bear the costs of buying licences or machines necessary for the usage of services related to the business. Since the argument is a topic of interest for this research, it will be analysed more in detail in the following section.

6.2 Cloud computing

6.2.1 Servitization and Cloud computing

Internet of Things (IoT), Cloud and Big Data are the three technologies that most enable the transition to new business models related to the concept of “Servitization” (18). Servitization is a process that requires companies to change structure and organization, transforming themselves into a system capable of selling, along with the product, value-added services integrated into the product itself. In this meaning, the services are not simply in addition to the sale of a product but become a central element of the offer itself. The property of the good is not transferred to the customer, but remains in the hands of the producer, who provides the customer with access to the good itself.
The growing diffusion of sensors on individual machines and production lines, the possibility offered by the cloud to exploit "on demand" remote resources for storage,

processing and access to data, together with analytics, which allow to work efficiently and quickly on huge amounts of data, structured and unstructured, coming from various sources, enable the process of service transformation: fundamental are in fact the return information, coming from the users of the good, on the state of operation of the product, on the performance, on the operating conditions. It is from the analysis of these data, in fact, that useful information emerges for the elaboration of contracts linked to the "exploitation" of the product in terms of pay-per-use, pay-per-availability, pay-per-performance.

Cloud Computing is revolutionizing the business model of industries and enterprises as dynamically scalable and virtualized resources are delivered as a service over the Internet. This model creates a new opportunity for enterprises. Cloud Computing is emerging as a major enabler for the manufacturing industry; it can transform the traditional manufacturing business model, help it align product innovation with business strategy, and create intelligent factory networks that encourage effective collaboration. (Lu et al, 2013) (19)

National Institute of Standard and Technology (15) defined Cloud Computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

6.2.2 Essential Characteristics

On-demand self-service. A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

Broad network access. Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

Resource pooling. The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacentre). Examples of resources include storage, processing, memory, and network bandwidth.

Rapid elasticity. Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.

Measured service. Cloud systems automatically control and optimize resource use by leveraging a metering capability (typically this is done on a pay-per-use or charge-per-use basis) at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, active user accounts). Resource usage can be monitored, controlled, audited, and reported, providing transparency for both the provider and consumer of the utilized service.

6.2.3 Deployment Models

Private cloud. The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

Community cloud. The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.

Public cloud. The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.

Hybrid cloud. The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

6.2.4 Service Models

Software as a Service (SaaS). The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email) or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user specific application configuration settings.

Platform as a Service (PaaS). The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

Infrastructure as a Service (IaaS). The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications, and possibly limited control of select networking components (e.g., host firewalls). (20)

6.2.5 A new Cloud Paradigm: Manufacturing-as-a-Service

Maas can be referred to as the concept that enables to match together the service user's demand for manufacturing service and manufacturing resource provider's offer of available manufacturing resources. Manufacturing as a Service entails giving manufacturing those features which are typical of services "the more any business resembles a service; the more likely it is to be able to create and sustain a competitive advantage and to secure long term profitability in the global marketplace" (Goldhar and Jelinek, 1990) (21).

Listed the main service features, the more of the following features are included in a business, the more it resembles a service and be successful in the future:

- High variety to the extent of customization of product design for each customer;
- Rapid adoption of new technology and concepts;
- Fast response time, short production cycles;

- Close linkage between producer and customer, very direct distributions channels;
- Flexible pricing and negotiated (contractual) relationships;
- High information content transactions between vendor and customer;
- Long term relationships in which both vendor and customer "learn" and become more efficient in their transactions with each other;
- Customer participation in the design of the product.

The service concept of manufacturing is a customer-oriented focus that shifts competitive advantage from factor costs to the firms' ability to innovate and to identify customer needs (Goldhar & Jelinek, 1990) (21).

6.2.6 MaaS foundations

The foundation of the Maas concept includes some technological enablers that are necessary for the realization of Maas into practice. Internet of Things, Cloud Computing, and Service Oriented Architecture represent the backbone of this new manufacturing paradigm (Wu et al., 2014) (22).

The Internet of Things, as explained earlier in the literature, allows interoperability between machines in terms of order data and product information, which are exchanged between different machines or production sites. Through IoT it is possible to monitor in real time, giving a clear view of the process flow within the company operations and the working parameters of the machines.

Cloud Computing is the enabler of the pay-as-you-go service model and the service delivery model of MaaS.

Service Oriented Architecture is a MaaS pre-requirement since it enables the sharing and the accessibility of manufacturing services, is a type of software design that allows to provide services by application components over a network, through a communication protocol. The concept of services introduced by the service-oriented architecture is one of the central components of Cloud Computing and without an underlying architecture built for the collection and provisioning of manufacturing services, MaaS would not be possible.

6.2.7 Evolution of manufacturing systems

In its initial application field of information technology (IT), Cloud Computing has proven to be a disruptive technology. Cloud based manufacturing (CBM) is the implementation of manufacturing-as-a-service paradigm into a Cloud Base System. Since its foundation are based on disruptive technologies, CBM is gaining significant momentum and attention from both academia and industry. Wu et al. in their paper "Old wine in new bottles?" (22) discussed the evolution of manufacturing systems, that undergone a number of major transitions driven by changing in market demand and emerging technologies.

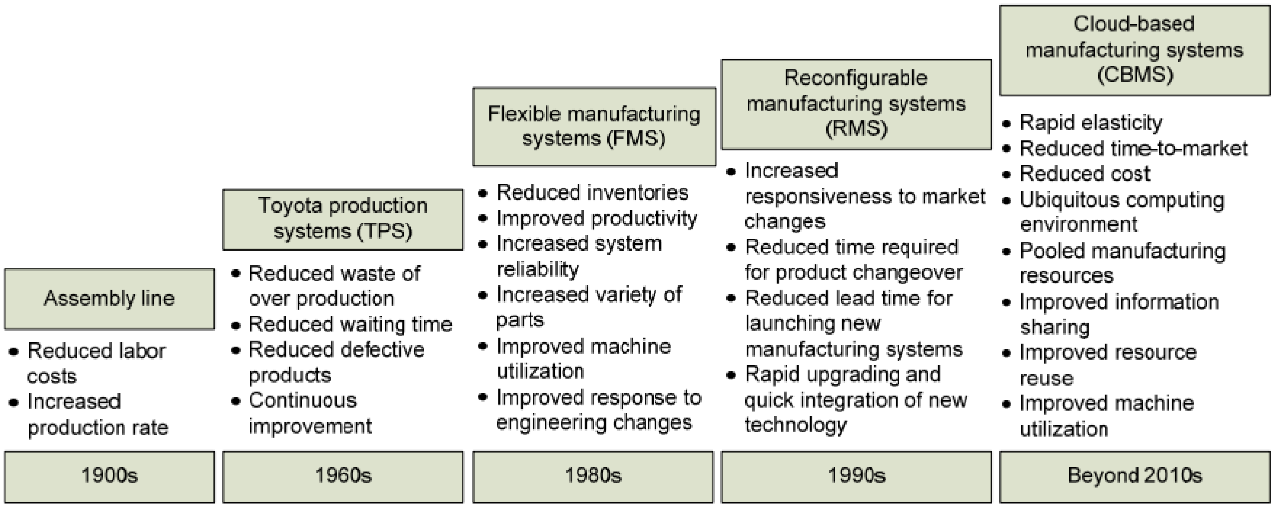

Figure 3: Representation of the evolution of manufacturing systems (Wu et al.,2014) (22)

The manufacturing systems presented fall into the category of centralized manufacturing with significant changes in machine tools, manufacturing plant layouts, and business models. With the development of the Internet, distributed manufacturing systems have been increasingly adopted by industry. With the emergence of Cloud Computing, CBM has become a promising manufacturing paradigm that will drive new manufacturing business models, leveraging common elements such as networked manufacturing, ubiquitous access, multi-tenancy and virtualization, big data and the IoT, everything-as-a-service (e.g., infrastructure-as-a-service, platform-as-a-service, hardware-as-a-service, and software-as-a-service), scalability, and resource pooling. Wu concluded that "cloud-based manufacturing is definitely a new paradigm that will revolutionize manufacturing, although cloud-based manufacturing is the result of evolution and adoption of existing technologies and manufacturing paradigms" (22).

6.3 Cloud Manufacturing

6.3.1 Overview

One of the first definition of Cloud Manufacturing was provided by Tao and al. in 2011 (23), describing it as a new computing and service-oriented manufacturing model that arises from the combination of emerged advanced technologies (such as Cloud Computing, 'internet of thing', virtualization, and service-oriented technologies, advanced computing technologies) with existing advanced manufacturing models and enterprise "Informationization" technologies. Since the concept of CM is based on already existing technologies, Wu et al. (22) discussed in their research whether it cloud be seen as a new paradigm that will revolutionize manufacturing or not. The authors managed to validate their hypothesis about the novelty of CM model by identifying a checklist of requirements that an ideal CM system should satisfy and comparing it with relevant manufacturing systems. The results are presented in the table 4, where the characteristics of the Cloud Manufacturing model are compared with the ones of web and agent-based manufacturing models. Web-based systems use the client-server architecture with the Internet to provide a light-weight platform for geographically dispersed teams to access and share manufacturing-related information via a web browser. On the other hand, agent-based manufacturing systems consist of agents (e.g., manufacturing cells, machine tools and robots) exhibiting autonomous and intelligent behaviour. It emerges that CM is a new paradigm that has the potentiality to radically change manufacturing, although it is the result of evolution and adoption of existing technologies and manufacturing paradigms.

Characteristics	Web-based	Agent-based	Cloud-based
Scalability	×	×	×
Agility	×	×	×
High performance computing		×	×
Networked environment		×	×
Affordable computing			×
Ubiquitous access			×
Self-service			×
Big data			×
Search engine			×
Social media			×
Real-time quoting			×
Pay-per-use			×
Resource pooling			×
Virtualization			×
Multi-tenancy			×
Crowdsourcing			×
Infrastructure-as-a-service			×
Platform-as-a-service			×
Hardware-as-a-service			×
Software-as-a-service			×

Table 1*: Key characteristics of a CM platform compared with Web- and Agent-based manufacturing (Wu et al., 2014)* (22)

6.3.2 Definitions

Various authors tried to provide their definition for Cloud Manufacturing paradigm, each different on the focus. Starting from Xu's simple definition "the manufacturing version of cloud computing" (24) a more exhaustive definition can be derived mirroring NIST's (National Institute of Standards and Technology) (15) definition of Cloud Computing:

- Cloud Manufacturing may be defined as ''a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g., manufacturing software tools, manufacturing equipment and manufacturing capabilities) that can be rapidly provisioned and released with minimal management effort or service provider interaction.'' (X. Xu, 2011) (24).

Echoing Xu definition, Wu et al. (25) concentrate more on the customer-centric aspect of Cloud Manufacturing and the benefits that it can bring.

- "Cloud Manufacturing (CM) refers to a customer-centric manufacturing model that exploits on-demand access to a shared collection of diversified and distributed manufacturing resources to form temporary, reconfigurable production lines which enhance efficiency, reduce product lifecycle costs, and allow for optimal resource loading in response to variable-demand customer generated tasking" (Wu et al., 2013) (25).

A more recent definition of CM is provided by Wei at al. (26), they do not only describe the need of shared resources as basis of the Cloud Manufacturing model, but they also mention capabilities and describe a way to distribute them.

- "Various types of manufacturing resources and capabilities are virtualized and made service-oriented to form a service cloud pool that can be unified and centralized for optimization management. The key to Cloud Manufacturing is to build a public product platform to realize the unified management of manufacturing resources and capabilities that can be accessed on-demand by users through the cloud anywhere and anytime" (Wei et al., 2020) (26).

Generally, all the authors agree on the fact that CM enables organizations and companies to visualize their resources on the cloud and provide them as consumable services over the Internet. Customers take advantage of these services according to their variable needs, ranging from product design to manufacturing, testing and management.

6.3.3 Participants

In the Cloud Manufacturing framework there are 3 fundamental roles, or participants:

- The Providers, who owns the physical resources and provide the manufacturing services involved in the whole lifecycle of manufacturing process. They can take the form of a person, an organization, an enterprise, or a third party. The providers are responsible for virtualising manufacturing resources and capabilities, transforming them into homogeneous cloud-based services and managing cloud-based services. (Wu and Xu, 2014) (27). They process the consumer requests based on manufacturing information from the operator and/or user.

- The Cloud Operators, who is responsible for operating and managing the platform to deliver services and functions. They deal with the organization, sale, licensing, and consulting of the manufacturing cloud services and provide, update and maintain the technologies and services involved in the platform. Operators interpret these requirements from the user and translate them into data for the production of the target product. Basically, they play an intermediary role between users and resource providers.

- The End users request and find Cloud Manufacturing services and then use them to meet business needs. The User can be either an individual or a company that purchases and consumes Cloud Manufacturing services, realized by the resource provider, by means of the cloud operator. The users supply engineering requirements describing the product to the cloud operator so that the manufacturing output meets the expectation. Users do not possess the capabilities to manufacture the desired product, so they rely on the competence of the cloud operator and the relative resource provider network (Wu et al., 2013) (28).

6.3.4 Physical architecture

Since Cloud Manufacturing is a relatively recent concept, there is discordance between the various research groups regarding the architecture that CM systems should have and the layers in which it is organised.

The platform's architecture should allow distributed resources to be encapsulated into cloud services and to be managed in a centralized way.

With this aim, Xu in 2011 (24) proposed a physical architecture made up of four layers:

- Manufacturing Resource Layer
- Virtual Service Layer
- Global Service Layer
- Application Layer.

The *manufacturing resource layer* comprehends all the resources that are required during the product development life cycle. These manufacturing resources can be divided in physical resources and manufacturing capabilities. Physical resources can exist in form of hardware (e.g., computer, servers, equipment, raw material) or software (e.g., simulation software, analysis tools, data). On the other hand, manufacturing capabilities are intangible and dynamic resources, these may include product design capability, simulation capability, experimentation, production capability, management capability, and maintenance capability.

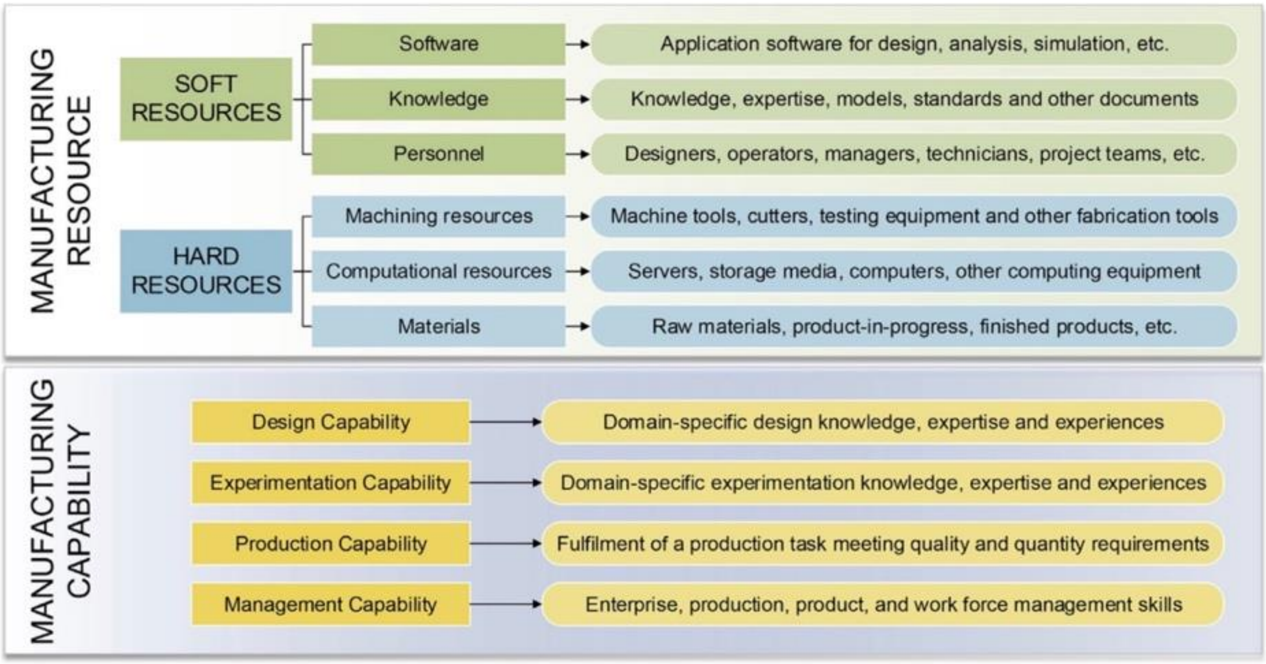

Figure 44: Structure of the manufacturing resource layer (Lu et al, 2014) (29)

The *Virtual Service Layer* has three main functions, that are:

- identify manufacturing resources
- virtualized them
- package them as Cloud Manufacturing services.

In order to identify manufacturing resources a number of technologies can be used, ranging from wireless sensor networks (WSN), Internet of things and GPS to clustering and analysis. Instead, manufacturing resource virtualization refers to abstraction of resources from their underlying physical entity. This is a critical phase since the quality of virtualisation determines the robustness of the infrastructure. The last function regards the packaging of the virtualized manufacturing resources to become Cloud Manufacturing services. It can be achieved through resource description protocols and service description languages.

Global Service Layer relies on a suite of cloud deployment technologies (i.e., PaaS). The resources virtualized and packaged in the previous layer are then managed using the Global Service Layer (GSL). The GSL, depending upon the task requested, can operate in two manufacturing operation modes: partial and complete services modes. In the complete service mode, the Global Service Layer takes full responsibility of the entire cloud operational activities. (Wu et al. 2013) (28). For what regards the partial service mode, the GSL does not handle all CM related activities, but some service provider provides additional input and operational activities.

The Global Service Layer is mainly responsible for locating, allocating, fee-calculating and remote monitoring the manufacturing resources. However, the hardware providers are still responsible for executing the manufacturing tasks and ensuring the quality of the manufacturing job. In order to guarantee an effective Cloud Manufacturing service, some critical technologies allowing resource selection and allocation methods are needed.

The Application Layer works as an interface between the user and the Cloud Manufacturing resources. This layer provides terminals for consumers, who can use it to construct manufacturing applications from the virtualized manufacturing resources. The interface can include simulation and design systems allowing the client to design the customized piece.

One important issue related to the Application Layer is the one of user-centric privacy. The main concern with Cloud Manufacturing for end-users is related to the storage of personal/enterprise sensitive data. This data includes not only product information but also information of some of the high-end manufacturing resources. However, Xu identified some technological solutions that can enhance data integrity, confidentiality and security, these are:

- Data compressing and encrypting at a storage level;
- Virtual LANs, that can offer secure remote communication;
- Network middle boxes (e.g., firewalls).

In the same year, Tao et al. (23) proposed an alternative architecture made up of 10 layers.

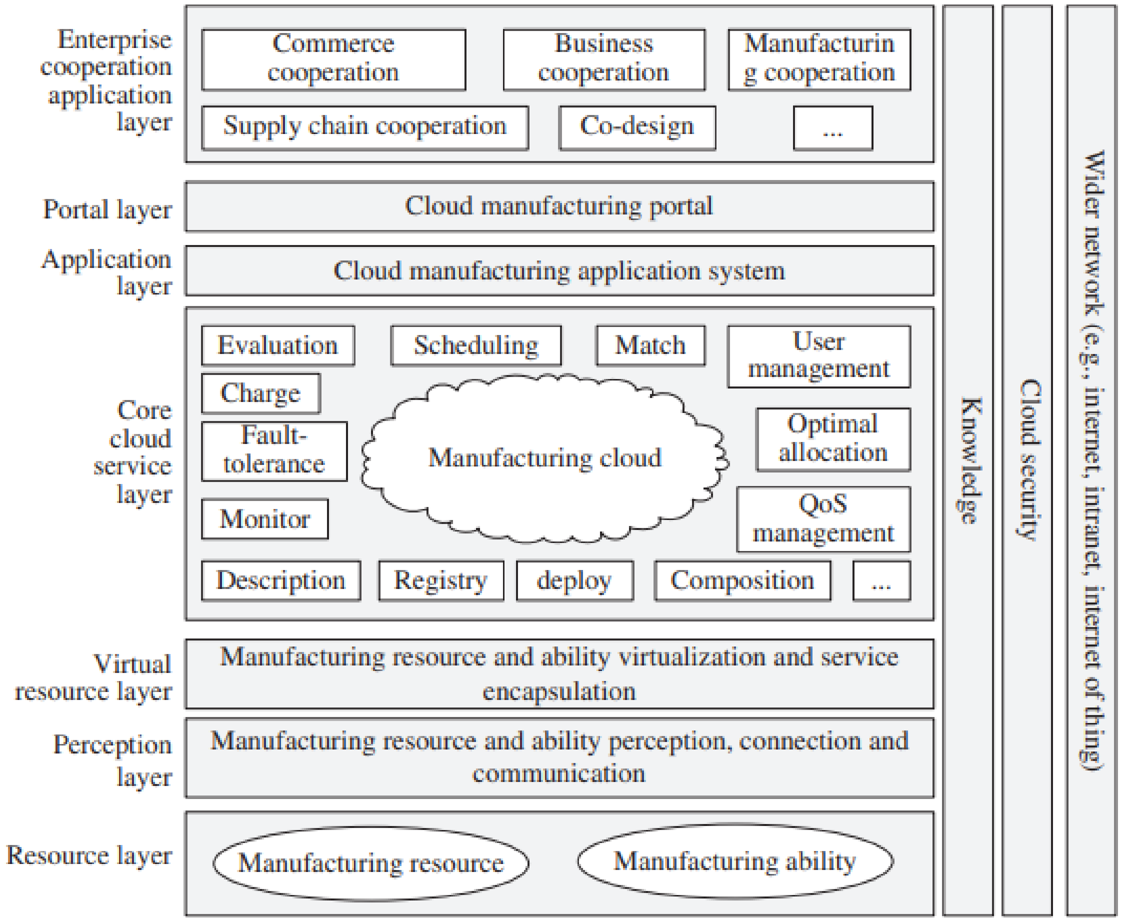

Figure 55: Architecture of a CM system proposed by Tao et al. (23)

While the characteristics of the *Resource layer* can be considered the same in both the architectural frameworks proposed, in the structure presented by Tao et al. (23) the functions associated to the Virtual Service Level are divided in two, leading to the conception of the *Perception Layer* and the *Virtual Resource Layer*. Passing through these layers, the virtualised resources are encapsuled into Manufacturing Cloud Services (MCSs). Then, the *Core Cloud Service Layer* provides core functions and service supports for the operation of the MCSs.

Differently for the architecture proposed by Xu (24), in this case the *Application Layer* is responsible only for the development of special manufacturing application systems according to specific demands, such as cooperative supply chain management system or CM-based ERP. Instead, The *Portal Layer* provides users with various man–machine interaction interfaces for accessing and invoking MCSs. Moreover, the *Enterprise Cooperation Layer* allow to realize different kinds of cooperation application, including commerce cooperation, business cooperation, collaborative design.

In addition to these "functional layers" of the architecture, Tao et al. (23) presented three more layers that supports all the functions of the platforms:

- The Knowledge Layer, which provides various knowledge needed in other layers such as manufacturing domain knowledge, process knowledge, model knowledge etc.
- The Cloud Security Layer, responsible of guaranteeing different security architecture, mechanism, and strategies for the system.
- The Wider Internet Layer, which provides the base communication environment to all resources, services, users and operations in the systems.

6.3.5 Interaction Process

Because of the existence of a large number of different architectural frameworks proposed by various research groups, it's difficult to schematise a general interaction process that a Company should follow when interacting with a CM platform.

However, Lu et al. in "Development of a Hybrid Manufacturing Cloud" (Lu et al., 2014) (29) made an attempt to provide such a representation. The model was framed specifically for hybrid Cloud Manufacturing deployment mode, but it applies also for the description of a general interaction process.

According to Lu et al., the whole manufacturing system receives as inputs four sets of data:

- Virtualized manufacturing resources
- Service requests from cloud users
- Historical service information
- Resource availability information.

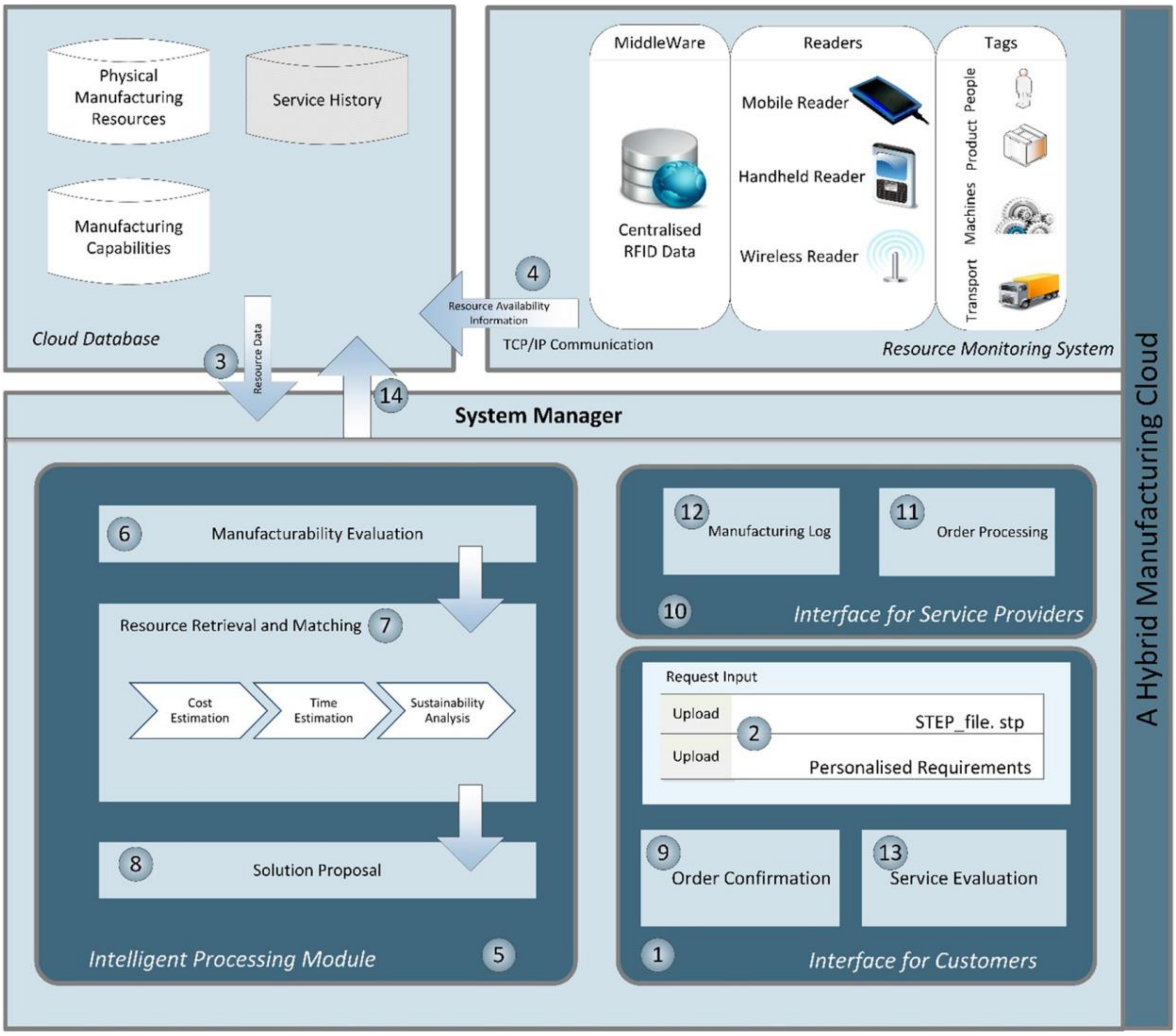

Figure 66: Representation of the interaction process for a hybrid Cloud Manufacturing platform (LU et al., 2014) (29)

Basing on these data, the workflow can be described in 14 steps, as represented in figure 6:

1. The user interacts with the platform through a GUI (Graphical User Interface), purposely designed for customers.

2. Using the customer interface, the user uploads its requests with customized requirements. This is one of the four input data the system receives.

3. Information about resources is delivered just-in-time to the System Manager.

4. The resource information is used to provide an accurate representation of the manufacturing site environment to the System Manager. Real-time resource availability information is gathered by real-time monitoring system.

5. When all the information is gathered, it is then processed by the Intelligent Processing Module (IPM) of the platform operator, which performs request analysis, request evaluation, and subsequently resource retrieval and service provision.

6. The request evaluation unit offers a comprehensive analysis for service requests by comparing new service request with historical data. It provides systematic analysis to detect service requests that are out of system capability. In this way, unreasonable services are identified at an early stage and expelled from the system.

7. Cost estimation, delivery time estimation and sustainability analysis are performed basing on the retrieved resources, this allows the system to send back quick quotation to the customer.

8. A solution proposal is made; solutions are then sent to the customer for the final decision on choosing the most preferable proposal.

9. The user decides for the most preferable solution, if any, and confirms the order.

10. Once the order is confirmed, it will be processed by the manufacturing service providers, for which there is an interface purposely developed. This happens in the case the provider does not coincide with the platform operator. Otherwise, the production is directly managed by the Intelligent Processing Module (IPM).

11. The order is sent to production and the selected manufacturer processes the order with the selected resource.

12. A manufacturing log is created, which is useful to record the manufacturing parameters (e.g., manufacturing lead time, resource usage, energy consumption etc.).

13. After the service transaction is completed, a service evaluation can be submitted by the customer.

14. The cloud database will be then updated with the manufacturing log and the evaluation of the customer, in order to improve the service.

However, it is important to notice that this represents provides only a guideline for how the whole Cloud Manufacturing process should work. When we are referring to real-world application, the processes behind different Cloud Manufacturing platforms can change a lot from one to another.

6.3.6 Technological foundations

This section discusses the fundamental requirements of a Cloud Manufacturing platform. The list is representative of the foundations you need to build on when creating a CM system, pointing out the functionalities necessary to support cloud providers and customers in realizing their business objectives.
Taking as a point of reference "Cloud Manufacturing: From concept to practice", made by Ren et al., 2013 (30) the list of requirements has been revisited and updated by the authors making a parallelism with Cloud Computing theories presented in section 5.2.2.

Distributed Resource pool

Virtualization

A cloud Manufacturing platform should be able to give a logical representation of real manufacturing resources, conceived with no physical limitation (Ren, Zhang, Zhang, Tao, et al. 2013) (30). Virtual resources refer to the logical version of corresponding physical resource. Virtualization enables support for building custom applications with flexibility.
Virtualization allows to create a multitude of virtual resources adopting a single physical system and to manage a multitude of virtual resources as if they were a single one. Moreover, is possible to perform changes and updates with a dynamic approach on the whole infrastructure.

Centralized Resource Management

Multitenancy

Multi-tenancy is a software architecture principle where each single software request is executed on a server and is able to execute multiple clients within multiple firms.

Management of Knowledge

The system has the ability to collect, store and manage users' requests and design projects.

Management of cloud services

The platform supports intelligent matching, finding suitable manufacturing resources on a cloud service catalogue in order to respond to customer's requirements.

Service Oriented

Servitization of manufacturing capabilities

Manufacturing capabilities are offered as cloud services to any user.

Instant Quoting Engine

Based on the input design and user requirements, the platform provides instant/fast quotation for each RFQ (Request For Quotation).

On-demand construction of virtual manufacturing system

Facing the submitted requests from customer, a cloud platform is responsible for discovering service solutions. Once a solution is confirmed by the customer and service providers, the responsibility of the cloud platform is to configure a virtual manufacturing system by assemble collaborative services as well as integrating the relevant resources. Typically, this virtual system is established dynamically according to specific requirements.

Rapid Elasticity

Infrastructure Scalability

Ability to scale up production capacity through access to new manufacturing resources accordingly to demand variation.

Broad network access

"Multi-sided" Platform

From a business perspective, the CM platform should represent the environment where sellers and buyers can handle business affairs such as negotiation and contract. The platform has the role of a trading market, where cloud providers sell manufacturing services and customer buy manufacturing services. The Platform need to be widely accessible and the potential to offer (manufacturing) services in different geographic areas.

Security and privacy

Security and privacy are a critical problem, especially for competitive enterprises. Cloud platform should provide a series of security policies that can be customized by end-users.

Management of social networks of cloud users

Three types of users, i.e., cloud providers, customers and operators, need to be coordinated through a Cloud Manufacturing platform. More importantly, these users are weaving a social network where materials, capital and information are flowing. Cloud platform need manage well these valuable networks, which will promote deeper collaboration.

Measured Service

Information Sharing

A Cloud Manufacturing platform should map each resource in term of manufacturing capability, by accessing machines information in real time, monitoring the orders progress status through sensors and software-machine communication that allow manufacturing resources to be connected together.

Evaluation and rating

A fair evaluation system is essential in order to build a society of trust in cloud production users. A cloud platform must support not only subjective evaluation by people but also objective evaluation by the platform using real historical data. This is also crucial for customers in selecting reliable service providers.

6.3.7 Opportunities

In literature, Cloud Manufacturing paradigm is regarded as a disruptive concept in the manufacturing context. "It can transform the traditional production-oriented business model into a service-oriented business model, enhance business management efficiency, and create intelligent factory networks that encourage effective collaborations" (Lu et al., 2014) (29). The model involves and benefits two key players: production service providers who provide their resources and users that pay for specific services. Through CM it is possible to access instantly the most efficient, innovative business technology solutions on pay-as-you-go basis, granting companies huge flexibility with no need to make costly capital investments in purchasing the latest technology manufacturing equipment, maintaining costs and training operators. In this regard, there is potential for participants to be both more efficient and more effective, one of the three "Devastating Features" referring to the theory of "Big Bang Disruption", which places Cloud Manufacturing as a potential disruptive element capable of revolutionizing the industry. (Big Bang disruption: a new kind of innovator can wipe out incumbents in a flash. by Larry Downes and Paul F. Nunes, 2013) (31). Derived from the above characteristics, a number of significant and long-lasting business benefits can be attained, including:

Financial flexibility: Cloud Manufacturing enables a shift from capital expenditures to operating expenses. The transformation to metered rather than upfront costs provides greater budget flexibility through the management of more variable costs, and a much clearer mechanism for allocating costs across the business.

Business agility: Heavy capital investment in manufacturing industry provides little business agility, which has a major impact on the profitability of an enterprise. With cloud adoption, this risk can be significantly reduced as the cloud offers the flexibility of terminating service provision based on feedback from the dynamic market and changing business goals with ease.

Instant access to innovation: Technological innovation and business typically grow in parallel, resulting in unprecedented growth across all industries. Although cutting-edge technologies are critical to business growth and improved competitiveness, most small and medium-sized enterprises (SMEs) cannot benefit from information technology advancements due to the upfront capital investment required. However, moving to the cloud liberates an organizations' intellectuals and finances to focus on technology innovation and business upgrades rather than purchasing or maintaining expensive resources. (32) (33)

6.3.8 Complexities

From the requirements necessary for CM realization, some evident issues arise. Primarily, CM requires a level of technological advancement sufficient to ensure full connectivity and interoperability of resources. Sharing resources is essential for CM to be successful as sharing computing, data and information is essential for Cloud adoption. However, these requisites are not accessible to everyone, as they require investing heavily in time and resource. That's why especially SMEs would have problems to sustain investments both to reach the targeted level of technology (machines and complex computer systems) and to train staff to acquire knowledge, skills and experience to manage these advanced technologies. The combination of technology and expertise is critical to performing key activities within the CM system such as production management, design, and product development, simulation, and real-time production monitoring. Another complexity related to the implementation of the model is represented by the adoption and acceptance topic. The model relies indeed upon the involvement of a large number of subjects along the supply chain, this implies a coordination of the parties for the attainment of a common agreement to achieve an optimal implementation. To earn approval, it is necessary to demonstrate to potential beneficiaries of the model that there are assessable benefits. However, to date, observable implementations are limited to a small number of cases. As a result, there are no quantitative models or methods that can estimate the savings provided, making it difficult to justify a move to CM. The security and its perception constitutes a concern, and it will be necessary to demonstrate that the information of all cloud platform participants are secure. Privacy is another concern for Cloud Manufacturing participants. Sensitive information disclosure is an issue that must be resolved through comprehensive contracts and by governments regulations. In the definition of a CM platform the discussion is still open about who should be the owner of the platform. Since the platform operate in different context, involving different roles, it is not possible to uniquely define ownership. The owner generally corresponds to the cloud operator, but in real CM examples not in all cases provider, operator, and user are 3 distinct roles. The platform owner should then represent the interests of all the parties involved, granting confidentiality, privacy, security and moreover a fair value distribution. As Adamson underlines in its literature review about CM, standard definition should be a prioritized research area. The standardization of basic and enabling technologies, as well as the procedures and methods for the complete operation of CM systems still need to be defined. Open standards and communication protocols are required, as well as support of 'plug and play' scenarios for machine-to-machine communication in worldwide production networks (Adamson et al., 2015) (34).

7. Cloud Manufacturing pioneers

In this chapter two cases of companies working as Cloud Manufacturing platforms are reported: Xometry and Protolabs. They both can be considered as on-demand industrial parts marketplaces providing custom and serial parts. The clients of those platforms provide technical drawings and precise specifications of the items that they need to be produced, usually in this phase CAD models are uploaded on the website. The platform, then, analyses the proposed projects providing real-time pricing and manufacturing feedback. If the part passes the evaluation, the customer can complete the process by specifying materials and quantities for the order. In both the cases reported, the services offered by the companies are not too complex manufacturing processes, such as CNC machining or 3D printing.

The main difference between the two cases is that while Xometry operates only as a marketplace, relying on a network of external supplier to manufacture the customized products, Protolabs owns in-house machinery that allows it to keep the production process within the boundaries of the Company. This results in different business models for the two platforms.

7.1 Xometry

Xometry (35) is an American CM platform founded in 2013. The company experienced a very fast growth in time, being one of the first actor to spot the opportunity offered by the adoption of cloud-based technologies and exploiting all the benefits derived from its innovative business model. The Platform puts in contacts two different group of clients: on one side there are small and medium size manufacturing companies offering specific competences and resources, in order to meet the customized demand of clients on the other side of the platform.

The Company reported $141MM in revenues for 2020 with a 92% CAGR between 2018–2020 (36). In 2019 Xometry acquired Shift, a Munich based on-demand manufacturing marketplace, which began Xometry Europe, allowing the Company to expand also in the European continent. Now the Company can rely on over 5000 suppliers across 22 countries. This make Xometry the global leader of the industry. The company operates in several different industries: Aerospace and Defense, Automotive, Consumer Products, Design Services, Education, Electronic and Semiconductors, Energy, Hardware Startups, Industrial, Medical and Dental, Robotics, Supply Chain and Purchasing. This is possible thanks to the heterogeneous set of manufacturing processes that they offer. In the specific, they can provide services of:

- CNC Machining
- Turning
- Sheet Metal Processing
- 3D Printing
- Injection Molding
- Urethane Casting

The business model of Xometry is based on its capability to provide a service that connects companies of different industries which needs customised components with manufacturers with specific resources and capabilities. The major advantages offered by the Platform are the reduction of delivery times and production costs for clients, the availability of real-time data on the status of production and the guarantee of quality control. On the other hand, small and medium manufacturers which have an excess in production capacity, are able to collect orders from all over the world. The service is provided through an online platform to which suppliers and clients can subscribe for free. Once they join Xometry, suppliers are evaluated with a score based on quality and on-time delivery, communication and engagement. The suppliers can also rely on some services of consulting and procurement.

In order to guarantee the perfect matching between clients' orders and manufacturers' capabilities the Platform relies on Artificial Intelligence that provides matching algorithms. The Xometry Instant Quoting Engine sits at the heart of the platform, powering the process. Customers upload 3D models of their parts to get started, and the quoting engine instantly analyzes the part's geometry and properties and then returns cost, expected lead time, and manufacturability feedback. In this context, an important resource of the Company is the Data Scientist Team responsible for machine learning and computational geometry As it has already been reported, Xometry can rely on a worldwide network of suppliers, which are responsible for the production of orders and their quality. For the transportation of the final products and their delivery, the Company made partnership agreements with logistic companies of different countries.
Xometry generates revenues by adding a fee on the value of production of every single transaction and thanks to the additional services that are offered to suppliers. On the other hand, the costs that the Company has to bear are mostly related to the development and management of the platform, considering also all the resources necessary for the usage of softwares to development precise algorithms and analysis. Another important cost item is the one necessary to ensure the quality control of all the pieces produced and the monitoring of the suppliers, that have to match the standards of Xometry (37) (38).
A summary of the business model of Xometry is presented in appendix B, basing on the business model canvas framework.

7.2 Protolabs

Protolabs (39) is an American company recognized as the world's fastest digital manufacturing source for rapid prototyping and on-demand production. It is a manufacturing-on-demand company which owns and operates all manufacturing equipment in house. The Company was founded in 1999 by Larry Lukis, a successful entrepreneur who wanted to radically reduce the time it took to get injection-moulded plastic prototype parts. His solution was to automate the traditional manufacturing process by developing complex software that communicated with a network of mills and presses. As a result, plastic and metal parts could be produced in a fraction of the time it was requested before. During the following decade, Protolabs continue to improve their techniques of injection moulding, it introduced quick-turn CNC machining and opened global facilities in Europe and Japan. In 2014, the Company launched 3D printing services that allowed product developers, designers and engineers to have easier and faster early prototyping and low-volume production.

The services offered by the Company are:

- CNC Machining
- Injection Molding
- 3D Printing
- Sheet Metal Fabrication

They are more or less the same as those offered by Xometry, and they allow the Company to operate in various industry. The most relevant ones are: Medical Devices, Electronics, Appliances, Automotive, Consumer Products.

The customers of Protolabs are companies of various industry, which are looking for custom-made components that meet their needs. The clients upload a 3D CAD file on the Company's online platform and then they select a manufacturing process from the ones available. Subsequently, the system performs a design analysis and within a few hours it sends to customers a manufacturability analysis together with real-time pricing. Once, that the clients review its quote and place the order, the production process starts.

Protolabs offers to the customers the possibility to receive customised parts within days, thanks to its automated quoting and manufacturing systems, which reduces manufacturing times and costs.

Differently from Xometry, in order to provide its services Protolabs does not rely on a network of external manufacturers, but it owns state-of-the-art in-house machinery. The Company is responsible also for the delivery of the pieces.

The revenues generated by Protolabs are for the major part related to the manufacturing of rapid prototypes and on-demand production parts. On the other hand, the main cost items are not only those related to platform management, as for Xometry, but also the ones necessary for the acquisition and maintenance of state-of-the-art machinery.

Also in this case, a business model canvas has been redacted, which is reported in appendix C.

8. Research Objective and Methodology

The research lays its foundation in the significant gap that has emerged between the literature on the Cloud Manufacturing paradigm and actual case studies. Various interpretations have been provided and much discussion has been generated regarding the characteristics of the paradigm, but the research effort has only been devoted to a limited number of case studies of early adopters.

The research aims to provide a case study of a Cloud Manufacturing implementation. The Italian footwear industry is the ideal candidate for the purpose of this research. Due to its complex structure made up of districts and its artisanal nature which has been severely impacted by big brands. The sector has the potential conditions to be renovated.

8.1 Research Questions

The research questions are the starting point of the logical flow of the entire study and have shaped its evolution and progress, leading to the natural generation of additional research questions.

1. **What is Cloud Manufacturing?**

   To answer this question, a detailed study has been performed on the origins of this concept and therefore it has been necessary to go back to Cloud Computing as an Industry 4.0 trend and the introduction of Manufacturing-as-a-Service paradigm.

2. **How does a Cloud Manufacturing business model work in real companies?**

   After understanding the potential of the model, the study continues with an analysis of real business cases

3. **Is the Italian footwear industry suitable to implement Cloud Manufacturing?**

   Having understood the theoretical requirements, the necessary characteristics, the benefits, the criticalities and having analyzed real case studies of Cloud Manufacturing models, the research continues with the study of the Italian footwear industry. The aim is to assess whether the industry can gain a competitive advantage from the implementation.

4. **How is a shoe made?**

   It is impossible to answer to the previous question without first understanding the dynamics, the processes, the components, the business structure and the historical background behind the creation of a shoe.

5. **Is "Italian Artisan" a real implementation case of Cloud Manufacturing?**

   During the research, this Italian start-up emerged as the first promoter of Cloud Manufacturing implementation in the footwear industry and case study was conducted on their business model.

6. **Is it possible to implement Cloud Manufacturing within manufacturing district in order to restore artisans' competitiveness?**

   following the findings of the case study, it was discussed whether it was possible to go beyond the vision of the Italian Artisan, moving Cloud Manufacturing to a more advanced level.

8.2 Research Purpose and Approach

The ultimate goal of this research is to determine whether it is possible to implement the model of Cloud Manufacturing in the artisanal contexts of the Italian footwear sector. The purpose is to relaunch the industry by interfacing artisans with the international market to create new business opportunities through the benefits offered by the paradigm.

In conducting the research all the steps to achieve the objectives were carried out with an entrepreneurial approach, with the intention of simulating a real market analysis to highlight the critical points and opportunities. Therefore, the studies of the industry, the interviews with experts and all the considerations have an approach aimed at providing a starting point for future developments to realize this project.

8.3 Research Methodology

Different methodologies were used to derive sufficient information to answer the thesis questions. The primary source was the review of academic articles, this provided a robust exploration and comprehension of the main topics covered. ResearchGate, Scopus database and Google Scholar were used as sources to access contents. Web search was also a key methodology for retrieving data on companies' business models and annual reports, and it was also used to simulate access to Cloud Manufacturing based platforms to better understand the dynamics of their models. In parallel with the academic research, it was necessary to develop an empirical methodology of analysis. After an initial analysis of the sector, it became clear that the Italian footwear industry is very complex, characterized by a production process that involves a large number of actors and is based on historical relationships among consolidated territorial structures. For this reason, the main source for valuable insight was derived from interviews with industry experts, entrepreneurs, managers, artisans, designers and with figures who, having to manage small family businesses, have visibility and understanding of the whole supply chain. The key experience that made it possible to get in touch with several different realities was the participation to two of the most important fairs of the sector, both hosted in the halls of "Rho Fiera Milano" in September. “MICAM” Milan, promoted by Assocalzaturifici, is the world's leading footwear exhibition. It is a unique appointment of its kind: the reference point for operators from all over the world Interviews; “Simac Tanning Tech” is the international appointment with the most qualified offer of machineries and technologies for the footwear, leather goods and tanning industries, which takes place in Milan, in concomitance with "Lineapelle".

The following sections outline a selection of the interviews that contributed most to developing the research.

8.3.1 Exhibitions

Micam – Alexio Cassani

Alexio Cassani is the Co-Founder and CEO of Stentle, a start-up specialized in the retail digital transformation and in e-commerce. Stentle's technologies allow to support the staff of the stores throughout the entire sale process, from customer recognition to the creation of a personalized path, bringing the logic of the online world into the physical shop.

Alexio participated to a conference about the future of the footwear retail which was held at Micam. After the conference, he was briefly interviewed by the authors. The interviewee provided a general overview of the state of technological advancement of the luxury footwear industry. In particular, he spoke about the possibility to implement a Cloud Manufacturing model in the sector. In his opinion, in the present there would be some implementation difficulties linked to the low level of technologization of most of the shoe manufacturers. However, some realities already started to move in that direction.

Simac – ICOL

ICOL is an international group with its headquarters in Barcelona, Spain. It emerged in 2019 over LACIT (Laboratory of Digital Technologies), a company that has operated since 2017 in the sphere of innovations and technologies.

ICOL Group was initially founded as an international innovative business, in which the various branches are responsible for their own developments in the framework of general programs on manufacturing and technologies. The Italian branch consisting of Sales and R&D Departments opened in 2020 in Milan. Apart from commercial activity in Europe, the branch is also dealing with AI and Machine Vision development.

Today, ICOL Group operates in six development centres and commercial offices in four countries (Spain, Italy, Belarus, Russia). The Group employs more than 300 full-time engineers.

The authors interviewed Andrey Golub, General Manager of ICOL Italy. He explained the services offered by the Company in the footwear industry, which are mainly of two kinds:

- B2B digital platform for the fashion supply chain management.
- Robotic cutting.

The B2B platform supports footwear companies in business management and in the development of new collections. In the opinion of the interviewee the companies can use the platform as Product Life-cycle Management software. ICOL helps the clients from sketch design to the development of new collections and to the realisation of a prototype.

However, the main business of ICOL Group is manufacturing with Industry 4.0 technologies. Applying these technologies to the footwear industry, ICOL is able to work the leather, cut it and guarantee other processes required for the production of shoes. A scanner analyses the leather and through AI understands the best use for it. Thus, a warehouse of raw materials is created. Then, the leather most compatible with the work that has to be done is selected from the warehouse and an algorithm optimises nesting before the cutting stage. In this way, the leather waste is reduced by 17%.

8.3.2 Companies

Nebuloni E.

Nebuloni E. takes its name from Eugenio Nebuloni, founder of the company. In 1954, after working as a finisher in a shoe factory, he decided to found its own laboratory and to focus his production on luxury women's shoes. From this moment on, the company took the structure it still has: a family-run artisanal factory. After the 80's the designer Eugenio Chiodero, Nebuloni's nephew took charge of the business.

Today, with the transition to the third generation, the Company is run by Alessio Chiodero. However, the brand preserved its identity over time by producing high-quality handmade shoes. Nebuloni E. is a small reality of the luxury footwear industry with 10-15 employees, depending on the seasonal production volumes.

The Company deals with both the production and the development of a shoe, supporting clients from the initial stages (e.g., technical drawings, prototyping, etc.) until the end of the production process. However, Nebuloni E. is mainly involved in the assembly of parts, while it outsources the production of the different components to trustworthy subcontractors.

The interviewee was Alessio Chiodero, who was also available to invite the authors to the plant, in order to illustrate closely the Company's operations and assembly processes. Since it was the first interview to be conducted, it was very useful to understand all the activities behind the production of a luxury shoe or the creation of a prototype. From the interview some criticalities about the adoption of a CM model in the reference industry immediately emerged. For example, Alessio highlighted the difficulty in interpreting what a designer wants only from a 3D drawing, even with specification, since the initial idea while is realised is often modified in accordance with the client. This results, in the need of continuos communication and exchange of information. In fact, is difficult to make a comfortable shoe with a pleasing design on the first try.

However, the whole development and prototyping phase would no longer be necessary, if a client asks for a model already produced by Nebuloni E. in the past. In this case, the Company can rely on an historical catalogue of models, to which it is possible to make a modification. This option allows the client to save time and cost, since the manufacturer would already have all the components available and all the machines set for production, and all the costs related to the new product's development can be saved.

Lastly, Alessio explained how in the last years almost the entire production is intended for a large Japanese retailer, with very few orders arriving from their website.

Roveda

In 1955, following in his father's footsteps, Giovanni Roveda and his wife started the Roveda brand in a small workshop with just a few employees. The brand quickly became popular in the shops of Milan and Paris. At the end of the 60s Roveda started to collaborate with high fashion brands such as Lanvin, Roger Vivier, Chloè, Emmanuel Khanh, Christian Lacroix, Valentino, Gucci and then in the 80s with Chanel (which acquired the company).

The collaboration with the famous French maison, transformed Roveda from a small footwear company into an industrial laboratory. Chanel acquired the Company in 2000, increasing its internal and external capacities and improving its production processes. However, the Company is able to carry on a tradition still linked to skilful manual work. Only a few steps in the production process implements completely automated technologies.

Another factor contributing to the company's success is the strategic decision to have a Research and Development Department: a team of around 50 people whose job is to transform an idea or a simple creative sketch into a shoe.

Today Roveda employs around 330 people, and it develops more than 1,000 different footwear models per year for brands from all over the world. In fact, The Company does not only develop and produce for Chanel.

The interview was conducted with the shoes technical manufacturing coordinator of Roveda, who explained to the authors how the shoes' development and production phases of a big brand like Chanel are organised. For each collection, Chanel develops the product internally together with Roveda. Subsequently, the Company can decide to produce the model in-house, or in case of simplest and most standardised shoe designs and in case of shoe models already used in the past, Roveda can rely on a number a network of subcontractors. In this case, the Company provides to the subcontractors a prototype, the materials and detailed instructions for each manufacturing process.

Thierry Rabotin (Parabiago Collezioni)

Parabiago Collezioni was founded in 1999 by three partners, Thierry Rabotin, Giovanna Ceolini and Karl Schlecht. The idea was to offer a very comfortable woman's shoe to a high-end market segment, with meticulous attention to detail. The Company experienced a significant growth during the 2000s, confirmed by the presence of the brand in the most prestigious shops around the world. This is demonstrated by the opening of single-brand boutiques in Paris, Rome, New York and Beijing.

Nowadays, Thierry Rabotin is among the few Italian shoe companies that still produce exclusively in Italy and buy all the components from Italian suppliers. The Company employs 70 people, and it produces around 100.000 pairs of shoes every year.

The interviewed was conducted with the chief designer of Thierry Rabotin, who explained how the production is almost entirely made in-house, except for leather parts and soles, which are then reworked internally.

Differently from the products of the other companies analysed, Thierry Rabotin concentrates mainly on the production of simpler shoes, for example wedges shoes, which have a thick sole instead of the heels. Dealing with a relatively simple product, in the opinion of the interviewee it would be possible to reproduce one of their shoe models starting just from a technical drawing.

Vittorio Valsecchi

The Company was founded by Giuseppe, Vittorio's father, who worked as a shoe artisan starting from the 20s. After gaining experience in various footwear companies in Italy and France in 1964 Giuseppe set up his own family business in Parabiago with his wife and three children.

His son Vittorio took over in 1971 and developed it into the new Vittorio Valsecchi shoe factory. Their products were sold initially in the Milanese shops of the 70s and then in the best Italian boutiques of the 80s and 90s. This fact testifies the company's growth, also confirmed by the start of direct sale channel: In the 2000s an outlet was opened to meet the great demand from customers. Today, the Company is run by Vittorio's sons Lorenzo and Roberto, under the supervision of their father. The shoe factory produces its own "Vittorio Valsecchi" line and collaborates with famous brands and emerging designers. Vittorio Valsecchi is a small reality composed of 15-20 employees, they deal with both the development and production phases of a model. However, a some of the production activities are outsourced. They mainly work with emerging designers, usually with demands that are difficult to develop.

The interviewee was Lorenzo Valsecchi, with whom the authors discussed about the possibility to create a platform on which the artisanal manufacturers could upload their existing models of shoes. In this way the designer and retailers interested in Italian luxury shoes could select their favourite products from the catalogue and could have the possibility of a limited customization. This kind of platform would allow to reduce costs and times related to the development and prototype phases.

Lorenzo explained how this solution would be convenient for manufacturing companies since they could re-use shoes' models on which they had invested in the past. However, he also highlighted some criticalities basing on his experience: on the customer's side (brands, retailers or emerging designer), this availability of old models could not be appreciated. In fact, each designer sees the development of the shoes as personal thing, they want to personally select the components.

Bottega23

Bottega 23 was born from the ides of two sisters who came from a family with a long history of manufacturing excellence. The brand offers to a classy women's audience shoes completely Made in Italy made according to the best artisan tradition.

Bottega 23 is a hybrid trading company: the take care of the procurement and coordinates the production of the various components. However, the Company does not perform any production or assembly activities internally. Once that the shoe is completed, Bottega 23 simply puts its logo on the product and sells it to retailers.

The interview was made with one of the two entrepreneurs running the Company, who highlighted various criticalities in the possible implementation of a Cloud Manufacturing model in this specific industry. The interviewee described the complexity of the luxury footwear sector, characterised by historical relationships with suppliers and by an elevate number of components that needs to be assemble in order to arrive to the final product (usually 30-40 components). Moreover, the market demands perfection and short response times. Bottega 23 is able to coordinates efficiently all the actors involved in the production process thanks to its experience and established relationship with suppliers. In the opinion of the interviewee, it is difficult for a Cloud Manufacturing model to perform the same task, since the industry is not yet highly industrialised, many processes are manual, and because of the great variability in the production of the parts, amplified by the fact that different items come from different suppliers. When the various components are put together, the risk that they will not fit is very high.

Italian Artisan

Italian Artisan, a reality created in 2015 by David Clementoni, is increasingly becoming a point of reference for international brands and entrepreneurs who want to make their products in Italy, coming into contact with the many artisanal companies that characterises the national industry.

Italian Artisan is a B2B matching platform that puts international fashion brands in contact with Italian manufacturing excellence and offers services that follow the entire production process, from prototyping to quality control.

In this case, the interviewee was David Clementoni, founder and president of the Company, who spoke about the functioning of the platform, its evolution overtime and the future objectives of Italian Artisan. Moreover, during the interview David explained the business model that characterises the Company and expressed his thoughts about the future of the luxury footwear sector. Italian Artisan aims at helping small and medium-sized manufacturers to compete with big brands on the domestic and international

market. David highlighted how the collaboration and coordination between these companies is the only way to prevent the demand for luxury shoes from being cannibalised by the big brands.
All the information gathered through this interview will be analysed more in detail in the dedicated chapter 10.

Mosaicon

Mosaicon is an artisanal shoe factory located in Vigevano (PV), it relies on 70 employees and produces around 100.000 pairs every year. It works for major international brands like Hermès, Chanel and Off-White. The Company usually receives the design of the shoe model from the brands, and then they collaborate to develop a prototype of the product. When these stages are completed, Mosaicon takes care of the production phase. It requests the components from a network of suppliers, while the Company handles the assembly activities internally, with the exception of the cutting and hemming activities.
The interview was conducted with the Purchasing and Production Manager of the Company, who explained in detail the actors involved in the prototyping phase of a shoe model and the timing required for design, prototyping and production.
The interview was useful in order to understand the value stream that characterises the industry, which is explained in detail in section 8.8.

8.3.3 Design School

Arsutoria

Arsutoria School was founded in 1947, at that time the aim was to train the footwear technicians needed in the shoe factories of Vigevano, near Milan.
However, Arsutoria immediately established itself as an Italian and international reference point for the training of footwear pattern-makers and today is recognised as the best school in the world for footwear and leather goods professionals. It offers its students

highly specialized diplomas and training paths, providing them with the skills to express their talent in making and designing shoes and bags all over the world.

The school is located in the center of Milan, the capital of fashion, the ideal place to build networks and to enter directly into the world of design and production of shoes and bags.

The interview with the school director Matteo Pasca was very useful to understand the dynamics that characterises the industry and the structure of the market. The interviewee explained to the authors how the industry in the last years is struggling, the only artisanal shoe factories that performs well are the ones on which the big brands rely for their production (e.g., Roveda). He added that nowadays very few shoe manufacturers know how to take care of product development, the major part of the small companies performs only assembly activities for third parties. Lastly, the interviewee illustrated to the authors the main components used for a luxury shoe and explained the actors and the dynamics involved in the prototyping phase of new model.

The information gathered in this interview had been the starting point to supply chain process in section 8.5 and the business structure in section 8.7.

9. Industry Overview

In this section an overview of the Italian footwear industry is presented, considering both the economic aspects and the characteristics of the sector related to a high presence of artisanal realities. Moreover, a study of the main trends that are emerging in the last decades is conducted. Lately, a description of all the components and processes necessary for the creation of a new model of shoe are described. This description is useful to understand the value stream map that characterises the industry and that is reported and explained in the research. The chapter concludes with an analysis of the structure of the footwear business and of its organizational framework.

9.1 Footwear industry in Italy

Italy is the leading shoe manufacturing country in the European Union, it holds the eighth place among world-wide footwear manufacturing countries in terms of volumes exported, but the third place in terms of value. (WorldFootwearYearbook 2020) (40)

This is the result of the fact that Italian producers sell shoes that on average have a much higher value, being Italy the undisputed leader among manufacturers of luxury and high-level shoes having a high fashion content.

For example, the footwear producers of Vietnam and China, that occupy the first two places both considering the volume and the value of exports, usually manufacture products that are much less complex than the Italian ones, concentrating on the medium-low range of the market. In these countries the companies manage to have low production costs, mainly because of minimum labour costs and the exploitation of economy of scale.

Instead, in Italy the industry is characterised by a number of artisanal manufacturers that have to bear huge labour costs, since a considerable part of the production process for luxury shoes is carried out by hand by highly experienced craftsman. In fact, for the manufacture of this type of products, a large part of the Italian companies does not rely on advanced machinery.

The Italian footwear sector comprehends about 4,100 companies and 72,000 employees (data for 2020), and an overall annual turnover that in 2019, pre-Covid, was around 14.3 billion euros (Data from Assocalzaturifici) (41). It represents a reality of extreme qualitative and quantitative importance in the Italian economy.

The footwear sector is very complex, the supply chain that characterised the industry includes a number of sub-suppliers of raw materials, tanneries, components, accessories, machinery manufacturers, model makers and stylists. The presence of multiple actors involved in the realization of the product requires considerable collaboration and coordination efforts for companies. The manufacturers usually rely on historical relationship with supplier, since the specifics of the components can be variable, and the results can change a lot depending on the producer. A change in the choice of suppliers could result in problems in the assembly phase of the final product, as the specifics of the components may not match between each other.

A consequence of the particular structure of the industry is the territorial concentration of companies and the formation of shoe manufacturing districts. The main districts are located in the regions of Marches, Tuscany, Veneto, Campania, Lombardy, Apulia and Emilia Romagna and cover 23 provinces.

9.2 Trends

In the last twenty years, the Italian footwear system has undergone a strong downsizing in terms of employees, companies and production volumes. The number of companies in the national industry dropped by 42,85% from 2000 to 2019 (pre-covid), while the production volumes experienced a fall of 54,01% in the same years. (Data taken from Assocalzaturifici[1]) (41).

The main causes can be found in the globalisation process and in the economic and financial crisis originated in 2008. The effects of globalisation mainly started by the entry of China in the World Trade Organisation (WTO) in 2001 and have led the Italian industry to face new and competitive economies from emerging countries. While the 2008 crisis had severely impacted the global demand for final products, compromising the domestic demand as well.

The national footwear industry, even if downsized in terms of production quotas, managed to rebuild its competitive advantages by increasingly shifting production towards the high range and towards higher value-added products, leveraging on its traditional strengths: the quality of the materials used and manufacturing techniques capable of combining traditional craftsmanship with modern production technologies, in a process of continuous research into creative solutions capable of creating an unmistakeable style.

This path of transformation and restructuring had to face over the past year a new crisis linked to the spread of Covid-19, a pandemic that has affected the global economy. In 2020, the Italian industry lost about a quarter of its total turnover (10,72 billion, -25,2% compared to the data from 2019) and national production. The annual "Made in Italy" production is 130.7 million pairs in 2020 (48.4 million less than in 2019, equal to -27%), for a loss of value around €6,1 billion (-23,9%).

The consequences on the number of companies and on the labour market in such a difficult year have already become evident: at the end of 2020, the number of active shoe factories in Italy fell to 4.152 (174 less than at the end of 2019, equal to -4%). In terms of

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[1] In the table reported in the appendix A all the data taken from the annual reports of Assocalzaturifici combined with data from other reliable sources are presented.

employees, the sector's workforce fell to 71.882 workers, accounting for -4% respect to 2019, with generalised declines in all the main manufacturing districts. Since the two-year period in 2009/2010 there had not been registered a reduction of this magnitude.

In this scenario, the only companies that perform well in the luxury footwear industry are the major brand like Gucci, Hermes, Chanel, Louboutin and so on. While small and medium-sized companies are forced to navigate by sight, accepting increasingly reduced production orders. In the last years, a lot of "big brands" have been acquiring companies of the industry in order to make them their production sites, or in alternative, they distribute their demand on a network of subcontractors.

In fact, the demand for branded products is almost entirely taken by the major luxury companies, while the small and medium size shoemaker that work with their own brand are struggling more and more.

Moreover, in the last decades a lot of companies in the industry decided to specialize and to keep under their control only some critical activities of the production process. A lot of small and medium artisanal shoe factories now only deal with the assembly phase of the product, outsourcing the production of components to trustworthy suppliers.

As a consequence of this situation a decreasing number of companies is capable of dealing with the development and design phase of a model.

9.3 *"Il Distretto Del Calzaturiero"*, Parabiago

The rise of footwear industry in Parabiago dates back to around the end of the 19th century. The city became famous in time because of the presence of a relevant number of shoemakers or workshops involved in this particular production.

These small family-run businesses have continued to operate for various decades, until the spread of industrial processes. The production of shoes at an industrial level started to develop around the 50s. Artisanal shoe factories began to expand their production and activities, facilitated also by the general capacity and experience in the sector, as well as the availability of cheap labour.

As explained before, originally the shoe factories carried out inside their plant all the phases of the production process. Instead, nowadays the outsourcing of part of the production activities, fostered the presence of subcontractors of parts and components on the territory.

There is increasingly more specialisation in production, always maintaining very high qualitative level, which lead the major Brands in the fashion field to choose Parabiago for the production of samples and products that are then distributed worldwide.

The "Distretto del Calzaturiero" is very heterogeneous and includes several different business realities, from small shoe factories to production plants of major brands. For this reason, various companies that are part of the district had been interviewed for the purpose of this research.

9.4 How It's Made?

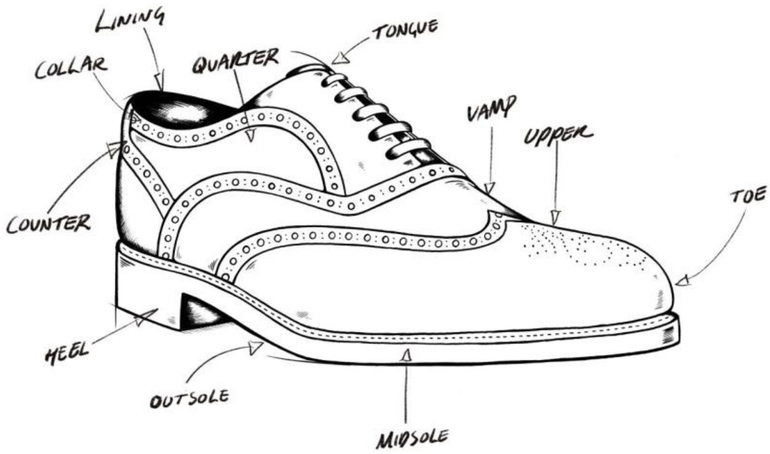

Figure 67: Anatomy of a Shoe (47)

In this section all the components necessary for the production of high-quality footwear are presented. Technically the term "**shoe**" is used to define the garments that serve to cover and protect the foot. If the footwear product protects also the ankle it is defined as "**bootie**", while it is referred as "**boot**" if it covers part of the leg. However, in this research the term "shoe" is used to define a generic footwear product, since the production processes are very similar for all the typologies presented. Moreover, the terms referring to the main components used for the production of men's or a women's footwear are the same, even if they change in shape.

With up to 30 individual components (42) used to make one shoe, there is also a long list of technical terms that describe each part. Starting from the macro-groups of components, each detail is further explained.

First of all, it is important to notice that a shoe is composed of two distinct groups of components:

The **Upper**: superior section that wraps the foot.

The **Bottom**: lower section that comes in touch with the ground.

The **upper** is usually composed of several parts:

- The *toe* and the *vamp* constitute the front part of the shoe.
- The *quarters* constitute the back part of the shoe.
- Some accessory components such as: *decorations*, *counter* (piece of material forming the back of a shoe to give support and stiffen the material around the heel), *tongue* (flexible piece of material that sits underneath the laces and quarter of a shoe) etc. Those components can be used, or not, depending on the model chosen for the upper.
- The *collar*: the top edge of the quarter, where you insert your foot (called the 'topline' on a dress shoe). It is often padded for extra comfort.
- The *Lining*: Most shoes include a lining on the inside of the shoe. These linings improve comfort, breathability and can help increase the lifespan of the shoe.

On the other hand, in footwear terminology the word "**bottom**" includes the following components: *sole, filler, waist, welt and heel.*

The *sole* is usually constructed of several layers:

- Outsole: The exposed part of the sole that is contact with the ground. As with all parts of the shoe, outsoles are made from a variety of materials. The properties the outsole need are grip, durability, and water resistance.
- Midsole: A mid-sole can be found on some shoes but is not always a requirement. The midsole is a layer between the in-sole and the outsole.
- Insole: This is inside the shoe and consists of:

- A construction insole that represents the basis for the construction of the footwear and has a junction element function between the upper and the sole.
- A leaning insole or insole, which has the function of covering the construction insole in order to make the finished shoe more elegant.

Filler: Elastic material such as cork or felt is used to fill the hollow between the insole and the midsole during construction. More commonly used on dress shoes of a more traditional construction.

Waist: The arch and in-step of the foot

Welt: A strip of material that sits between the upper to the sole to ensure a secure bond.

Heel: The thick piece of leather or rubber that's attached to the sole of a shoe to raise and support the back of the foot. Dress shoes tend to have a separate heel piece, which can be replaced if necessary.

The bottom can be constituted by a single piece that groups together all, or some of the above detailed components: with this productive modality a **mono-block bottom** is realized, frequently obtained by molding through CAD computerized systems.

Among the **elements of closure** of the footwear are *laces, hooks, eyelets, buckles, buttons, elastic seals* and *zippers*. (43)

9.5 Supply Chain Process

In this paragraph all the activities necessary for the creation, development and production of a new footwear model are presented. The authors listed in detail all the activities taking as reference a generic luxury shoe model. (44)

Modelling stage

The initial phase in the shoe production consists in its "ideation", defining the characteristic models through the work of stylists. In this phase, some sketches are designed. Basing on them, technical drawings are made with the support of the model-maker if necessary. In fact, the designers often do not have the expertise to provide the specifications necessary for production. Later, starting from the technical drawings a prototype is created. Once that the final prototype is completed, there is a sampling phase in which the companies understand if the new product has enough demand for the beginning of the production. However, this phase is not analysed in this section, since it is not related to the production of the new model, but it will be deepened in section X.

The last stage of modelling consists in the engineering of the components: companies provide to the suppliers the exact specifications and quantities of the items needed.

For what regards the design and prototyping phase, two different methodologies can be followed: *Traditional Design* and *CAD Design*.

Traditional Designing

The stylist or pattern-maker proposes a model of footwear executing sketches or designs on some paper sheets. The model represents the outline of the footwear that is going to be manufactured.

The shoe-last maker in collaboration with the pattern-maker, starting from these drawings, realize the first sample of the shoe (last).

In the case of complex footwear, the pattern-maker traces the stylistic lines on a dimensional structure, subsequently it covers the shape entirely with adhesive papers and on these it draws profiles, stitching, lacings and all the other details of the model.

Then, the 3D model is brought to a 2D dimension by transferring the drawings present on the adhesive papers on a flat sheet (flattening) and creating the so called "camicia" or standard, on which are reported all the specifics of the parts composing the upper of a standard size shoe (usually size 37 is taken as refence).

After these operations, starting from the basic model of standard size, the development of all the sizes (called grading) and the engineering of the model is carried out through two main activities:

- The addition of assembly margins, engraving of references for stitching and gluing etc.
- The creation of cardboard models of the various pieces of the upper part that will be used for the realization of the prototype, for the production of the series of cutting dies, or for hand cutting.

Later, the prototype of the heel, of the sole and of the insole are realized in collaboration with specialized factories.

Finally, the prototype of the footwear is obtained, consisting of the upper elements in cardboard and the bottoms, heels and soles in wax or wood. The final model is judged by the producer, eventually modified, and finally inserted in the sample book.

CAD Designing

Computer-aided design, introduced since the 1980s, is based on CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing) software applications, characterized with graphical interfaces.

This technology simplifies the phases of drawing, grading and engineering.

Two main CAD systems can be used:

- The *three-dimensional programs* (*3D CAD*) that allow the patternmaker to interact on screen with a three-dimensional "object", such as last, upper, heel and sole, in a manner similar to how it is traditionally done;
- The *two-dimensional programs* (*CAD 2D*) in which the design process on computer is relative only to the upper, and begins a step further downstream, that is from the "camicia" already developed.

Manufacturing stage

Once that the ideation, preparation and development phases are realized in the modeling department, the real production process begins in the cutting and shearing departments.

In these departments the cutting and shearing of leather is carried out using specialized machines. In the cutting department uppers, linings, reinforcements and insoles are prepared; in the shearing department, soles, heels, top-pieces, welts, shanks and other accessories are made. In the sewing phase, the uppers are assembled and sewn together, while in the binding department, the seals are mounted on the uppers using special sewing machines. Always for decorative purposes, on uppers made of leather or plastic material, it is possible to perform processes to obtain patterns of various geometry and decorations. Then, the assembly of the upper on the last is performed with the use of special machines. The counter, the toe-puff and the other reinforcements are inserted in the upper. At this point the upper, assembled to the insole, after having passed through the ironing oven, is prepared for the application of the sole. For the realization of a good assembly, numerous and differentiated conditioning treatments are carried out on the upper that needs to be assembled and lately on the assembled shoe.

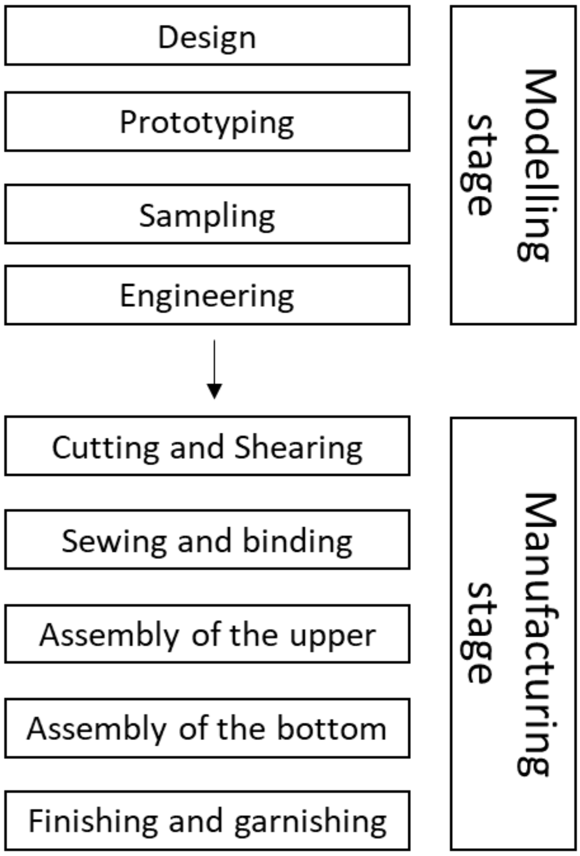

Figure 78: representation of modeling and manufacturing stages

In the bottom department the sole is anchored to the upper with various methods (glued or cemented system, Good-year system, Blake stitching system, Ideal system); in synthesis the sole is glued or stitched to the upper (which is already mounted on the insole), with the use of a special press/stitching machine.

The final application of the heel is also carried out in the bottom department. Subsequently, the finish department consists in the finishing of the parts that compose the bottom: the grinding, by means of rotating machine tools, of the heel and the sole; the coloring and waxing of the perimetral part of the sole by means of machines equipped with a rotating tool called "lissa"; the polishing of the heel and the whole sole. Those activities are followed by operations of embellishment of the footwear carried out in the garnishing department: the waxing of the sole, the cleaning of the upper with solvents and/or brushes and the polishing before boxing.

The number and difficulty of the operations for each of the phases described depend largely on the type of footwear produced. Another important factor is the quality of the article, whether it is valuable or mass-produced, as this decision affects the choice the technologies to be used, as well as the organization of the work and the materials used.

9.6 Customization process

In recent years, companies in the industry have been paying particular attention to the changing needs expressed by consumers, favoring the process of customization of footwear more than in the past. In fashion footwear generally customization does not concern the structural elements of the shoe, but it focuses in particular on aesthetics and on the possibility of varying components or materials for the upper. The elements that compose the structure of a shoe are the last, the sole, the insole and the heel. These components cannot be easily modified, since a change in one of them would require a modification of all the other items. In this case, the shoe would have to go through the prototyping phase again, creating a completely new product.

There is the possibility of producing variations basing on articles already in the catalogue of a company. The catalogue is composed by model already produced in the past, which can be customized starting form an existing footwear structure (same last, heel, sole and insole).

9.7 Business Structures

9.7.1 The geographical dimension

The distribution of footwear companies presents the typical features of district-based manufacturing. Within the luxury footwear industry, the traditional areas of Marche

Veneto and Emilia, together with Tuscany, continue to form the backbone of the national system. This is not only the result of industrial tradition, size of production and employment but also of the presence of companies that for several years have chosen to adopt a development model centered on internationalization, quality and high creative content.

The deep transformations of the market caused by the increasing competition of emerging countries and the competitive repositioning towards productions of medium-high segment have imposed to the companies of the district to exceed the model of geographical proximity, based on the research for specializations within the network of micro and small businesses linked by a relationship of cooperation and competition. The transformation pushed the companies to exploit the opportunities for production and consumption beyond the national borders, to invest in processes and technologies capable of increasing the quality of products, and to develop new marketing and distribution models. The territory, in this perspective, offers a competitive advantage in the extent to which it manages to provide favorable conditions for the development of this new business model.

9.7.2 The current productive/organizational framework of the footwear industry system

Industrial market

One of the main effects of the shift towards higher-end footwear production that has taken place in the last years is a redefinition of the relationships between final and intermediate local companies. The leading firms have begun to orient their outsourcing choices considering the ability to guarantee quality and reliability as a key aspect for the suppliers. This fact has only partially contributed to bring back works inside the original districts, since the companies search for quality supplier even outside the national borders.

The need to reset relations with specialized suppliers in order to find the best solutions has led to the development of models for the progressive enhancement of the role of these third parties, who are often called to carry out a real co-design of production. This activity demands increasingly exchange of information made possible by the spread of computer connections and shared platforms.

In the recent years some leader companies emerged from the typical district structure. These companies are able to coordinate the entire productive process also through externalization of the production. The committing footwear company at the top of the value chain is thus transforming itself into a sort of tertiary company that, starting from the continuous observation and interpretation of the signals coming from the market, designs models and gives production instructions by co-designing together with suppliers and subcontractors.

Apart from the leader companies, in the national footwear industry, there are a variety of production models and an articulated series of relationships involving final and intermediate companies. For what regards the final companies, they could be either companies capable of covering the entire production process (vertically integrated companies) or companies concentrated only on the higher value-added phases, also companies that do not have production facilities at all but concentrate exclusively on the phases of product design and/or commercialization.

As it concerns the intermediate enterprises, the typical model regards those enterprises that do not control neither the phases upstream (as the ideation and development of the product) neither the ones downstream as the distribution. Moreover, they do not have direct relationships with the final market neither own a brand. The district intermediate enterprise can assume the characteristics of a sub-supplier and/or of a tertiary company. In the first case the company realizes one or more phases of the production process specializing itself in the production of semifinished products and/or components of the shoe (e.g., the upper, the heels, the bottoms, the soles or the accessories) or realizes a specialized productive service (e.g., the assembly or the realization of the forms basing on technical specifications of the customer).

The tertiary enterprise, instead, has the control of the entire productive process from the design of the form to the assembling and to the packaging and it can itself rely on sub-suppliers. There is then a hybrid dimension present in the industry, in fact it can happen that the same company realizes two product lines, one on behalf of third parties and one destined directly to the final market adopting its own specific brand policy.

The encounter between advanced final enterprises and specialized intermediate companies tends to delineate the new relationships of business in the more advanced districts.

These relationships are often based on collaboration and co-design that help to generate innovation through a continuous process of problem solving.

Bespoke

The competitive landscape of the Italian footwear industry is further characterized by the reality of made-to-measure. These companies are able to undertake almost all the phases of the production process thanks to manual skills and a high level of expertise. The companies that survived in this business area base their competitive advantage in making "one of a kind" product with high margin.

Bespoke footwear, known to most as "custom" or "made-to-order" footwear, represents the heritage of traditional shoemaking. True custom shoemakers don't merely create footwear, they produce tailor-made works of art to fulfil clients' desires.

9.8 Value Stream Map

In the luxury footwear industry, companies generally establish long-term relationships in order to improve collaboration with their suppliers and subcontractors, as it was already explained. The modelling phase is key for those companies that deal also with the product development. The suppliers are involved both during the design and the engineering phase in order to produce the components necessary for the footwear in accordance with the specifications required by the company. The suppliers' selection is a critical phase and aims at obtaining the highest possible level of quality and innovation at a competitive price. The main categories of suppliers can be divided into: leather suppliers and tanneries, last makers, sole makers, heel makers and insole makers.

The suppliers generally do not work exclusively for one company, but develop both standard and exclusive products (e.g., soles and heels may be protected by patents). Most of the suppliers are regional and located in different footwear districts.

Moreover, many stages of the production process are generally outsourced. Thus, the companies establish long-term relationships also with subcontractors, which are based on the quality of production. The subcontractors usually work on a single-contract basis, and the footwear company monitors production and the progress of orders, also with people on site.

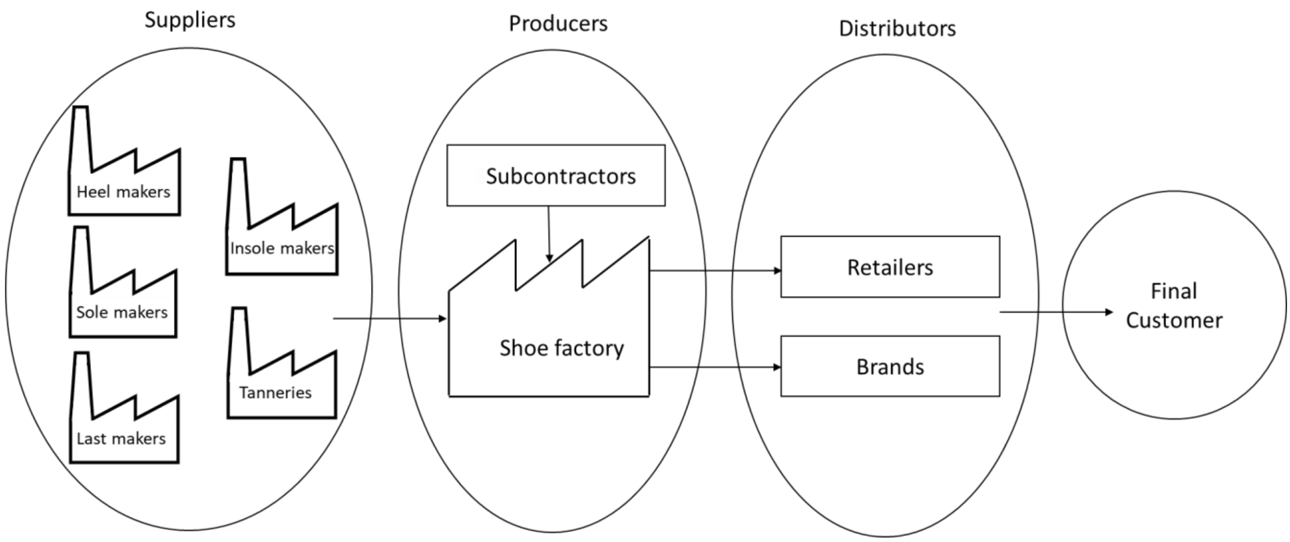

Figure 8 9: Supply network of the luxury footwear industry

Since the modelling stage is at the hearth of the process that leads to the production of a new model of shoe, the companies dedicate to this phase high resources in terms of time and costs. In this section the modelling stage is analysed in all its phases, to understand the dynamics involved and the timing that they require. In order to do this, the authors imagined the case of a final company that deals with the development of the product and that relies on a network of suppliers to obtain the components necessary for the creation of prototypes.

The modelling stage can be divided in four main phases: design, prototyping, sampling and engineering. During the design phase the stylists, together with the pattern-makers, realize the drawings of the new model of shoe. The drawings then are used as basis for the realization of the prototype. In this phase the company that is dealing with the development of the new product needs to contact all the necessary suppliers. Since the creation of a prototype is not a linear process, all the actors involved in this stage needs to be coordinated. For example, the heel-maker needs to have the last for the creation of its components, and if any change occurs during the development of the prototype, it is very likely that all the main components will be modified.

During the prototype phase, more than one prototype is created. The first prototype requires an average of three weeks in order to be produced. After its completion, the Company evaluates the possible modification and the defects that can be corrected. At this point the creation of a new prototype starts, in this case the timing required is a bit lower, since all the suppliers have already been warned. The creation of a second prototype on average requires 2 weeks. After this step, the Company makes further adjustments and passes to the sampling phase. The time required for the final adjustments and the creation of samples is on average two weeks. Usually most of the companies stop at the second prototype, however there are cases where even a third one can be developed. In these cases, an additional week is required.

The main objective of the sampling phase is to check whether the new model of shoe receives positive feedbacks from the market, so that it can be moved to production. During the sampling stage the new model is presented in fashion shows, industry fairs and showrooms. Alternatively, the product can be sponsored through photo shoots for advertising campaigns or through representatives. At the end of this stage, there is an order collection period, during which it is decided whether the product has met expectations and can move on to the production phase.

However, before production, the engineering stage is required. In this phase, the Company makes arrangements with suppliers to obtain the components needed and it sets the in-house machinery for production. These steps are taken with the aim of increasing production efficiency. Moreover, if the Company relies on subcontractors for the production, very precise working instructions are created so that shoes produced externally by different companies do not look too different.

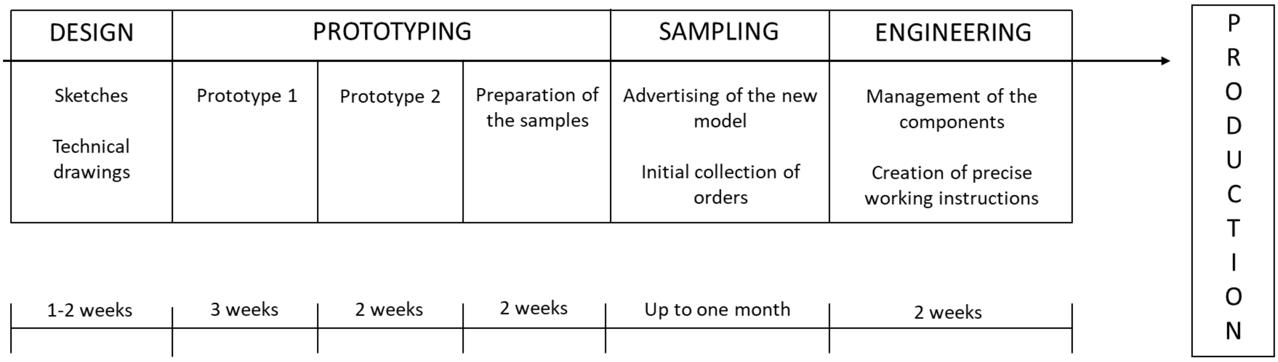

Figure 910: Stages of the modelling phase with average lead time required

The phase that requires the most effort in terms of resources and time spent is the prototyping one.

During the prototyping phase a company works on four levels:

- Bottom
- Materials
- Last
- Model

As already explained in the section describing the components of a shoe (section 8.4), the main components included in the bottom are the heel, the sole and the insole.

The heel can be made using different materials, but mainly wood or plastic are employed. The same applies to the sole, for which leather or rubber are usually used.

The bottom is the more complex part to manage, since the decision made at this stage on the materials to be used for its production will heavily influence the costs and timing of the whole development and production processes.

If the heel is made in plastic, a mold is required for its production even if it can imply significant costs. In this case, the component is characterized by high fixed costs (the ones related to the mold), but low variable costs, since the production process is very simple once that the mold is realized. On the contrary, a heel made of wood requires milling and it have lower fixed costs, but higher variable costs. However, for what regards the prototyping phase, the timing with the two materials is similar, since if the component needs to be produced in plastic, the heel-makers usually rely on 3D printing during this phase. A similar argument can be made for the sole, which requires a mold in the case it is made of rubber.

For what concerns the materials, the companies can require components that the tanneries already have in stock, or they can commission personalized components. Depending on the decision, costs and timing can vary. For example, a customized leather processing requires an average of two weeks.

For the creation of the last the timing depends mainly on the relationship established with the supplier. If the company has an historical relationship and if it is an important client for the last-maker, the last can be completed also in a few days.

The management of the model, instead, regards all the small changes and variations that can be made to the original idea. These changes do not take long if they are done on technical drawings (usually hours), but they affect all the other levels of the prototyping phase.

The situation reported above is related to the case in which a company requires completely new components from the suppliers, which have to manufacture the items starting from scratch. However, sometimes the companies that want to create a new shoe model rely on items that have already been used in the past, modifying them or combining them with completely new components. In this case, it is said that the companies rely on some “carry over”. This situation allows for savings in time and investment costs.

10. Towards the Smart Footwear Factory

The footwear industry, in recent years has been able to radically transform itself by managing to shift from mass production to quality models offered in different pre-built variants. Today the sector is under the pressure of a demand that continues to require high quality but at the same time seeks an extreme customization in taste and style with non-standard shapes and finishes. Therefore, the evolution of demand imposes to the footwear system to develop a continuous process of technological innovation supporting the production process in order to introduce new materials, new shapes, new styles. This process would ensure high quality standards essential to maintain competitiveness in high-end products. The innovation must also embrace the evolution of distribution models in order to guarantee greater speed with respect to the time it takes to enter the market, even in relation to a greater variety of products or to a personalization of footwear that the demand of customers increasingly requires. In order to cope with these dynamics and with the aim of growing in the global market, the main effort of national footwear companies must be to succeed in raising the levels of operational efficiency through innovation. The footwear production system, despite the presence of so many excellences in all its productive articulations, overall is still weak in terms of ability to activate innovation processes and investment choices. The investigation on innovation system during the interviews, registered a widespread delay in the adoption of innovative practices: the productive segment still relies on an intensive manual approach that still manages to satisfy demand. The new push factor that could accelerate the processes of transformation is undoubtedly represented from the possibility to approach the technological opportunities of industry 4.0 (supported from an extraordinary plan of incentives to the investments), developing productive models based on the paradigm of the intelligent factory. This is an industrial production model that, in its broadest sense, aims first of all to promote flexible and adaptive processes to solve problems arising from increasing complexity and in which automation plays an important role, as a combination of software, hardware and/or mechanics. Therefore, for the footwear industry it is a question of moving from processes organized according to the logic of intensive manual skills, to production lines in which creativity, style and production knowledge of a craftsman are expressed in the ability to interact with operations carried out by digitally-guided machinery for maximum precision processing, which would be otherwise unfeasible for the production of increasingly personalized products. There is then another development perspective that the new intelligent factory can bring: trigger processes of manufacturing reshoring in order to bring back in Italy productions for the mass market in the productive segments of medium-low cost. Automation and digitalization would guarantee gains in efficiency and productivity such as to make it convenient to install production lines in Italy for lower value-added products aimed at the mass market.

10.1 Factory 4.0 Models in Footwear industry

In the wide meaning attributed to the concept of factory 4.0, the literature identifies, especially within large manufacturing companies, some main enabling technologies that underlie the smart factory:

- Internet of Things (IoT),
- Big Data Analytics,
- Cloud Computing (Cloud Manufacturing)
- Additive Manufacturing
- Automation through Robotics

Through these new technologies, the factory acquires efficiency, gains in competitive ability and can adapt and customize production with respect to the increasingly diversified needs of demand. The interconnection between all business functions and the human-machine cooperation, not only behind the company but along the entire production chain, can improve the quality of both products and processes in a perspective of orientation to the final consumer and increasingly customized production.

Optimization of the production process and the ability to design and manufacture increasingly high quality and customized products require a complete management of the entire production process, including logistics and distribution, since the two functions play a strategic role in meeting the needs of customers, acquiring inputs and quickly supplying products. The production system of the so-called " Smart Factory" is therefore an integrated system driven by ICT technologies and automation in which man interacts by governing processes in a flexible and creative way and where the needs of the final consumer are the basis of all production and distribution choices. In the attempt to systematize the new productive paradigms of the intelligent factory and to offer a shared taxonomy, multiple studies and documents are now in circulation, also of institutional nature, which try to trace a theoretical framework on the basis of the recorded experiences and on the possible evolutions.

These models have found application in very advanced production experiences and the presuppose for their realization is a decisive innovative acceleration that represents the real challenge for footwear companies in the coming years. First of all, however, the sector is made up of small and medium-sized companies, and it must face a cultural challenge that is substantiated by the need for companies (Ares 2.0 2016) to take note that the new factory must:

- *Reorganize* processes according to a more efficient logic,
- *Equip* itself with a technological system that allows a more flexible production oriented both to product quality and to customization towards the end user,
- *Rethink* the human-machine relationship in a non-substitutive but integrative key.

In the next chapter, the case study "Italian Artisan" is presented, a Start-up born with the aim to involve and make competitive again the small and medium enterprises, that represent the heart of the national footwear sector. Over the years, these artisanal realities have suffered the effects of financial crisis, globalization and changes in demand and market needs. The presence of large multinational brands has reduced the volume of sales of less structured companies, which, having no means, no resources and little predisposition to corporate cultural change have rarely interfaced with the international market. This has led to a reduction in the number of SMEs by half in the last decade. To stop this trend "Italian Artisan" proposes a business model based on Cloud Manufacturing to interface small and medium-sized companies on the international market and to restore competitiveness to the sector while preserving its traditional essence. (45)

11. Case Study: Italian Artisan

In this chapter the case of an innovative Italian start-up that operates in the luxury footwear industry is reported. Since the Company seems to present the typical characteristics of a Cloud Manufacturing platform, the authors analysed in deep the services offered by the Start-up and its functioning in order to assess whether it can be considered the first example of a CM platform in this specific industry.

11.1 Company Profile

Italian Artisan is a B2B marketplace that connects international brands, retailers and designers with authentic Italian artisans by providing online tools for the creation or customization of luxury products.

The Company was founded in 2015 by David Clementoni, with the mission of "bringing the Italian manufacturing tradition into the future of commerce through simplified digital tools which allow to discover, compare and source the best Made in Italy products" and it was awarded as "Best European Start-up in the Fashion category" at the Start-up Europe Awards (SEUA) in 2017 and 2018.

The Platform can be used to purchase customized fashion products, from apparel to bags and accessories. However, the reference point of the marketplace is the luxury footwear industry.

In the last years Italian Artisan has grown exponentially with a continuous and progressive increase in the number of artisans who rely on the Company to get in touch with brands they would have never known otherwise. Right now, more than 500 Italian manufacturers are registered to the platform. In a similar way, also the number of international brands which choose Italian Artisan has grown constantly to more than 5000 brands, scattered in 32 countries.

In the coming years Italian Artisan aims to become a reference point for both international brands wishing to produce in Italy, and for manufacturers/artisans who want to internationalize.

11.2 Clients' side

The main clients targeted by the platform are the international brands, emerging designers and retailers. They can sign to the platform for free and look for personalised artisanal products.

The Platform offers two types of services: the customer can create a completely new *Private Label* project or can chose to customize an already existing product from the *White Label catalogue.*

The two types of services attract different kinds of customers. The retailers which want to order a production batch are more likely to interact with the White Label's part of the platform. On the other hand, an international brand or an emerging designer is probably more willing to express its innovative ideas through a Private Label project.

11.2.1 Private Label

This part of the platform is dedicated to the clients who wants to create an innovative project starting from their own drawings. In order to help them, the platform offers also a range of services that support the customers in all the phases of the production cycle. The services vary from helping the client with the design and the technical drawings to selecting the best craftsman for the project, but they include also support during the prototyping phase, production supervision and quality control. All these additional services are provided by Italian Artisan in return of a predefined fee.

Starting phase of the project

In the first step of the process the platform asks the client some initial information like the name of the project, its target (man, woman or kid) and the category (shoe, bag, clothing etc.). Then, the customer is asked to select a sub-category, regarding the type of product that they want to be produced. For example, a client can start a project dedicated to a luxury shoe or to a less complex type of footwear, like a sneaker.

After the selection of the sub-category, the customer is asked to select the materials that they want to be used in production from a proposed range, and to provide an idea of the budget that they are willing to spend for the realization of the project (fig. 11).

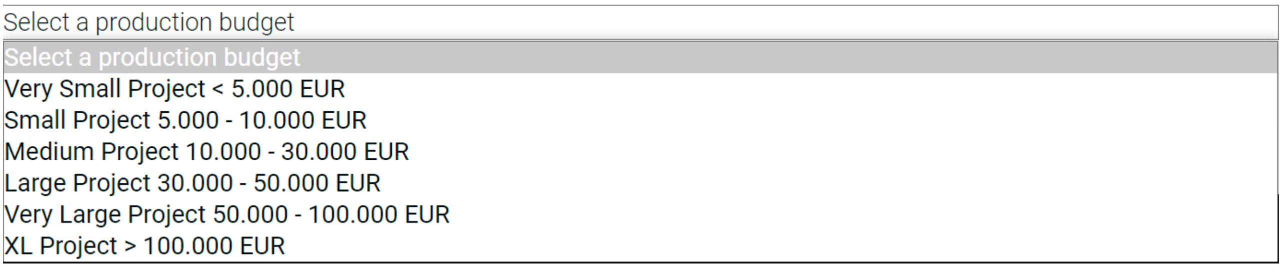

Figure 11 11: Price range suggested by the platform

Lastly, the platform asks to upload on the website spec sheet, tech packs, technical drawings or images of reference. In this phase, the more precise the provided documents are the easier will be to find the right artisanal manufacturer.

Receipt of proposals

Once the first phase is completed and the project's drawing is uploaded, Italian Artisan publishes a tender addressed to the producers registered on the platform. The manufacturers are notified through the web-page, they review the project and respond with a proposal including price range, timing and additional manufacturing feedbacks.

The clients receive the proposals, evaluates them and, after that, they are able to negotiate directly with the manufacturers to select the partner that best meets their needs.

Start of production

After the customer has chosen the most suitable manufacturer, the production can start, and the platform helps the client to keep track of the production process reporting on a specific part of the web-site the status of production. Also, during this phase the platform allows the customer and the manufacturer to be constantly in contact. In fact, through a dedicated webchat they can exchange attachments, documents, invoices and everything related to the project in progress.

Additional Services

The platform provides additional services for the clients who wants to start a *Private Label* project. Different services are offered to support the customers during various stages of the new product's development. A client may experience difficulties in different phases of the process, due to a lack of experience or capabilities. In this case a team of technical experts gets in contact with the customer, helping it with its needs and guiding it along the following stages.

The services offered can be grouped according to the phases in which they support the client:

- Product Development Service
- Raw Materials Sourcing Service
- Manufacturer Scouting Service
- R&D Dedicated Support Service
- Quality Control Service

The *Product Development Service* is intended to support the client in creating the stylistic design proposal. A "Lead Designer" provides the stylistic proposal of 3-4 ideas per product, assists the customer in the choices of materials and colours, and helps to arrive to a final design by means of rendering.

This kind of service can be applied on one product, or up to a maximum of ten product, depending on how much the customer is willing to spend. The basic service costs 299€, but it can go up to 2399€ if it's requested for more products and if more attention and precision are required.

The service is provided through an initial alignment video call and then some reviews with the Lead Designer are set, the number of the reviews depends on the type of service requested. The timing can vary from 3 to 8 weeks, basing on the amount of work needed. If a client is only interested in translating the proposed design in into technical drawings ready to go to producers, they can choose a dedicated service called "technical design program", which is worth 225€.

With the *Raw Material Sourcing Service,* a dedicated technical team supports the customer in the search for required materials and accessories. The team compile a raw material file together with supplier contacts, it requests samples on behalf of the customer and then sends introductory emails to present the project to the suppliers. Basing on the quantity of materials and accessories that the client wants to source, and on whether it is interested in sustainable materials or not, the cost can range from 179€ to 1709€. The timing is of 3 or 4 weeks.

Choosing the *Manufacturer Scouting Service* a team of technical experts helps the client to select the best possible manufacturer who can meet his/her needs. The team provides the customer with background reports about each producer, including its track record of quality and expertise. Moreover, the experts offer support during pricing negotiation on pattern making, sample making and production.
At the beginning, the technical team has to undertake a deep analysis of the project. Then, once that the client has selected the preferred producer basing on the advice of the experts, it is assisted in making a video-conference with the selected manufacturer. The cost of the service can be 499€ or 599€, depending on whether the client is interested in sustainability issues like respect for the environment, reduction of waste and emissions, circular production process, use and recycling of clothes. In this case additional services are provided by the team, for example an ethical and sustainable background report about each manufacturer is redacted and shared. The service usually last for 3 weeks.

With the *R&D Dedicated Support Service* a dedicated local Product Manager helps the client in the risk mitigation of prototype and sample development, and in the coordination and supervision of these two phases. Moreover, the Product Manager is in charge of the quality control during the prototype/sample development process, and of the compliance with the agreed delivery times. The service costs 1497€ and the average duration is around 8 weeks. However, the support lasts until the requests are completed.

The *Quality Control Service* is also provided by an expert local Product Manager, who performs quality control based on the clients' needs. They can offer a "bulk production quality control" or a "custom control", in this latter case the customer can contact the platform to have a tailored program. The service is worth 1499€.

11.2.2 White Label

In this case the clients do not need a brand-new design, but they can choose between a catalogue of products uploaded by the network of suppliers. For what concerns the footwear industry, the catalogue is composed by the shoes' structures offered by the manufacturers. Starting from the structures, which is the fundamental part of the shoe (as explained in section 8.6), a certain degree of customisation is offered to the customers. In fact, they can decide colour, materials and size. In some cases, the client can talk directly to the producer to agree on minor changes like the addition of accessories.
Choosing this option, the customers avoid R&D costs related to the design and prototyping phase of a new shoe model and a quicker time-to-market can be guaranteed.

Customization process

Once the client has selected a shoe's structure among the one presented, the process of customization starts.

In the first step, the platform asks the customer about some general information, regarding the possibility to put a logo on the product or the preferred packaging.

The next step is the selection of the variant, in this section the platform communicates to the clients some information regarding the specific product, as the minimum order quantity (MOQ) that they have to respect, the production strategy and the estimated production time.

Moreover, the web-page provides a list of all the modifiable components, specifying the available materials that the customer can select for the item and the possible colours.

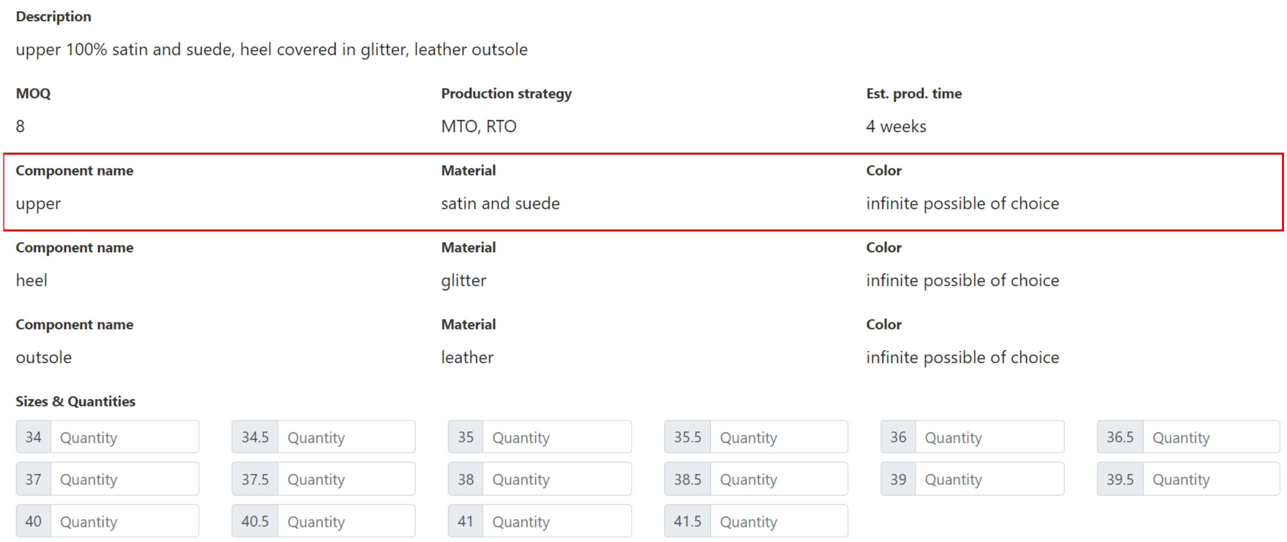

Figure 1212: Example of the part of the platform dedicated to the customizable components

For example, in the case reported in the fig.12 the upper part of the shoe the materials available are the satin and the suede, both of them are available in all the possible colours. These choices will be made once that the client will get in touch with the manufacturer in the following steps of the platform.

The last part of this section is dedicated to the quantities that the client wants to order. A range of different sizes is available, and the customer simply has to digit the desired number of pairs that they wish for the specific size. The platform provides the subtotal of the order for each pair that the client selects, to help him/her to continuously keep the cost under control.

In the last step the information regarding the order is summarized, and a dedicated section is available to allow the client to write notes about the level of customization that they want. Here the customer can select the preferred materials and colours for each modifiable component, basing on what was reported in the second step of the process.
Once that the order is submitted, the client will simply have to wait for the product delivery.

11.3 Manufacturers' side

The artisans who register in Italian Artisan are interviewed by the production team following a targeted screening process, they must provide a Chamber of Commerce certificate and all production specifications. Authentic Italian craftsmanship can be recognised by its quality and attention to detail up from the raw materials selection. This is what the international fashion brands are looking for.
The registration to the platform is free from charge for the manufacturers, and they are allowed to receive unlimited production requests. However, they have the possibility to subscribe to certain services offered by Italian Artisan. A manufacturer can enter the "Selected" subscription service or the "Premium" one. With the former, the producers are given priority respect to others, and they can receive more targeted production requests. Instead, the latter also provides them with commercial assistance. The cost of the "Selected" service is 69 €/month, while the "Premium" one costs 199 €/month.

11.4 Business Model[2]

The advantage of a B2B platform is the efficiency, while traditional artisanal companies rely on inefficient channels of supply and distribution, even if they have a deep

[2] The business model of Italian Artisan is summarised using the Business Model Canvas in the appendix D

knowledge of Made in Italy products and production. Italian Artisan combines the efficiency of a B2B platform with the know-how of the traditional manufacturers thanks to a team of experts. The Platform can be used to place production orders for various fashion products, from apparel to bags and accessories. However, the reference point of the Company is the luxury footwear industry, and almost all of the services offered are related to this area.

The target of the platforms on the one hand are international brands, designers and retailers who want to produce high-quality products relying on the expertise of Italian artisans, which is recognized globally and considered as a source of added value. On the other, there are the Italian manufacturers, who want to expand their production thanks to the orders of international clients.

A small or medium-sized international brand wishing to produce in Italy faces a considerable number of obstacles in terms of costs and organisation. In fact, it usually does not know how to find the most suitable producers or which contacts to rely on in order to find it. Moreover, the development phase of a footwear product is very complex and comprehends different actors that need to be coordinated. An international company can hardly do so, and even if it could, it may find difficulties in monitoring the production process once it is started.

Italian Artisan simplifies this path, since the core activity of the platform is to put in contact the international brands with local manufacturers who have the necessary know-how to satisfy their requests.

Moreover, the Company offers services that follow the entire production process of new product, from prototyping through to production and quality control.

In the last year Italian Artisan also provided to the international clients the possibility of customizing a product already in the catalogue, without all the activities related to the development of a completely new product and reducing the time-to-market as well as costs. The catalogue was created asking to the manufacturers subscribed to the platform to upload some of their models.

On the other side of the platform, the artisanal producers register for free, joins the Italian Artisan Community and receives requests for projects from clients all over the world. They can also decide to purchase a subscription to gain greater visibility and services like commercial assistance.
In order to provide its services, the Company relies on a team of experts, which are part of Italian Artisan and have great experience in the industry. This allows them to coordinate ad manage the different phases of a new product development. Instead, the management of the platform is entrusted to Wink, which has been a partner of the Company since the beginning.
Another key partnership is the one with DHL, which allows Italian Artisan to take care of the delivery of orders once they are completed.
The Company is able to turn the services that it offers into revenues by adding a fee on the production value, the percentage of the fee is around 12% of the value. In addition, Italian Artisan earns money through the support services that it provides to brands, retailers and designers (presented in section 10.2.1), but also thanks to the subscription services offered to manufacturers (section 10.3).
Moreover, the Company requires a payment of 100€ for every sample or production shipment, which is provided thanks to a partnership with DHL.
The costs that Italian Artisan has to bear in order to tun its business can be divided in three macro-groups:

- IT Resources Costs
- Staff Costs
- Marketing Costs

The It Resources Costs are the ones related to the acquisition of hardware and software products or services. Looking at the 2020 financial report, which can be found on the web platform for equity crowdfunding Opstart, during the past year the Company invested 25.363€ in technical services, software programming services and other activities aimed at implementing the web platform for the provision of B2B services. These costs alone represented around the 20% of the total production costs reported in the income statement, which includes amortization and depreciation costs.

The Staff Costs are another relevant cost item. At the beginning of 2021 the number of collaborators was around 10 people. But it is expected to grow rapidly, considering that there is a need to manage the requests of the increasing numbers of international brands and retailers signing up to the platform.

At time now, Italian Artisan has not made any invested in Marketing yet, except for those related to public relationships and the participation in trade fairs (like Micam). However, as it is explained in the following section, the plan for the next three years is to invest heavily in this aspect in order to attract as many international brands as possible. Marketing investments will be made also to attract artisanal producers, although to a lesser extent.

11.5 Future Plans

Italian Artisan is an innovative SME, which is currently in the seed stage, and it is experiencing exponential growth: in the first few months of 2021 alone, the turnover achieved is equal to the entire turnover of 2020 (+100%). Moreover, they have an average 100 new brands and 20 new manufacturers joining the platform every week. These data are taken from the interviews reported on various websites related to crowdfunding (Crowdbase, Startupswallet and Opstart). The interviews were made in June 2021 with David Clementoni, Founder and President of the Company, and of Olga Iarussi, Co-Founder and CEO.

The Company's stated objective is to arrive to 60.000 brands and 10.000 artisans registered in the community. The aim is to become the reference point for the brands that want to produce in Italy and the artisans who wants to access the international markets.

In order to foster its growth and achieve its goals Italian Artisan started an equity crowdfunding campaign on Opstart with 50.000€ as target. The campaign was very successful, since it went overfunding with the investors that provided much more money than the ones requested. In fact, 195.697€ were collected. These money will allow the Company to exponentially accelerate growth over the next three years. In fact, a specific three-year plan was redacted and presented to the investors on Opstart's online-platform. The funds raised will go 35% into Marketing in order to attract new brands and manufacturers. 35% into Technology to expand the services offered on the platform and improve the "white label" services, the aim is to increase the catalogue of products that manufacturers already have in their catalogue. Finally, 30% of the funds will be used to strengthen the sales team.

Moreover, from the interview that the authors conducted with David Clementoni, it emerged the possibility that in the future the platform will also address the B2C market. But this purpose is very difficult to achieve in a medium-short period, since it necessitates the development of completely new structures for the collection of orders and distribution of final products. However, in this perspective the white label service could represent a growth opportunity, since the final clients could select the models of shoes that they prefer from a catalogue of existing products. In the present, the biggest limitation is the difficulty of providing customisation for minimum production batches.

11.6 Assessment

Referring to the literature review on Cloud Manufacturing, the business model of Italian Artisan has been confronted to determine the similarities and differences with the theory. The assessment aims to determine to what extent Italian Artisan is based on the Cloud Manufacturing model and to highlight possible opportunities for future development.

11.6.1 Definition's assessment

With regard to Cloud Manufacturing definitions, the one provided by Wei et al., 2020 (26), is the more representative for Italian Artisan. Especially when he refers to Cloud Manufacturing as "public product platform to realize the unified management of manufacturing resources and capabilities that can be accessed on-demand by users through the cloud anywhere and anytime". In fact, the platform has a feature in common with the theory: it is the place where supply and demand meet, a centralized cloud service that virtualizes different types of resources and production capabilities and allow them to be accessible for the users everywhere and every time it is needed. Instead, according to the definition proposed by X.Xu (24), there is a clear point of divergence from the theoretical concept: "manufacturing resources can be rapidly provisioned and released with minimal management effort or service provider interaction". Italian Artisan, as a service operator, plays a key role in managing and connecting manufacturers with customers, but in performing this task it employs considerable managerial effort, with dedicated team composed for this purpose.

11.6.2 Key requisites assessment

Below, Italian Artisan's platform is compared to the fundamental requirements, presented in section 5.3.6, that characterize the Cloud Manufacturing paradigm according to the academic literature (distributed resource pool, centralized resource management, service oriented, rapid elasticity, broad network access and measured service).

Italian Artisan manages to offer manufacturing capabilities as cloud services to any user.

Concerning virtualization, this concept is limited to "white label" manufacturing, by providing a service with minimal customization and flexibility that depends on manufacturers availability. However, the system is built on an infrastructure that has the potential to give a logical representation of real manufacturing resources, conceived with no physical limitation as stated by theory. The architecture of the platform allows to manage in parallel the requests of several clients within multiple firms through the multi-tenancy principle. The system has the fundamental requirement of "knowledge management", which enables users to view, upload and manage design projects. The platform does not support intelligent matching and rely on expert operators to find suitable manufacturing resources on a cloud service catalogue in order to respond to customer's requirements. Based on the input design and user requirements, the platform ask to suitable manufacturers to provide quotation for each RFQ (Request For Quotation). This process is a step away from the literature that envisions a platform that can provide instant/fast quotations. Building the virtual manufacturing system on-demand is not something Italian Artisan manages; it merely directs demand to the most suitable manufactures, leaving them in charge of managing the supply chain process. The platform has succeeded in assuming the role of a commercial marketplace, where cloud providers sell manufacturing services and customers purchase manufacturing services. It is widely accessible and allows (manufacturing) services to be offered in different geographic areas. Regarding the management of social networks of cloud users, the platform offers a variety of services aimed at both manufacturers and its users, thus succeeding in managing these valuable networks, which will promote deeper collaboration. Scalability is a crucial point in Cloud Manufacturing, but the platform is not fully exploiting this feature since order productions are assigned to single producers. Therefore, demand variations require ability to scale up production capacity within the same manufacturer, which is not always possible. Involving several manufacturers to respond to a common order is not always feasible, it depends on the specific shoe required and the complexity of the manufacturing process. Each manufacturer has different machinery and different working techniques, which leads to a high variability in the output. To determine the reliability and quality of Italian manufacturers Artisan records historical data and supports both objective and subjective evaluation of its service providers.

One other main gap of Italian Artisan's network with respect to theoretical concepts is the absence of a service measurement system that allows real-time information sharing. The platform offers the only option of monitoring order status, which is updated by the manufacturer. A Cloud Manufacturing Platform should map each resource in terms of production capacity, accessing machine information in real-time, monitoring the progress of orders through sensors and software-machine communications that allow production resources to be linked together.

12. Conclusion and future development

From the analysis of the case study on "Italian Artisan" it is possible to conclude that the business model presents the main characteristics on which Cloud Manufacturing concept is based. The start-up has gained a lot of interest and visibility in the industry, creating a widening network of connections between producers and customers. The project, conceived with the mission of relaunching the Italian artisan economy, is showing promising results and with the upcoming finalization of the crowdfunding campaign is now preparing for scale-up. The economic sustainability of the business model is based on the possibility of connecting Italian artisans with international demands. The key for the success of "Italian Artisan" lies in the creation of new business opportunities in markets that would be difficult to reach by small, unstructured manufacturing businesses that struggle to gain visibility and lack the necessary means to compete in markets outside national borders. As a result of the process of comparison between literature and Italian Artisan business model and after an in-depth study of the dynamics that define the footwear sector, clear criticalities have emerged. The project is ambitious and faces as a consequence the problem of feasibility. The main challenge for Cloud Manufacturing implementation lies in coordinating the dense network of players involved within the supply chain. With over thirty components, on average, in a shoe and processes that involve several producers of specific parts in a continuous cycle, the sector has inevitably developed in districts where these relationships have been consolidated over the years. For this reason, "Italian Artisan" to overcome this problem leaves the management of the supply chain to manufacturers. The level of digital and technological innovation that characterizes the majority of companies is still at a state that precludes the implementation of Cloud Manufacturing. It is therefore necessary to undertake a transformation process capable of bringing SMEs of the sector to the Industry 4.0 standard. The challenge then becomes to find a way to economically support the transformation. "Italian Artisan" is demonstrating that a structure based on Cloud Manufacturing is able to bring benefits, although not exploiting the full potential of the paradigm. A possible future development, able to both develop Cloud Manufacturing model and support in parallel the digital transformation and technology is represented by the "District Cloud Manufacturing", a platform that would connect companies planning to develop new model of shoes, with suppliers who offer components already produced in the past and ready to be used and modified for new prototypes.

12.1 District Cloud Manufacturing

The idea originates by leveraging on a critical issue that emerged from the studies about the industry and Italian Artisan business case. One of the most significant costs for manufacturers resides in the new models' development process. Companies always incur in significant development costs when they want to create new shoe structures. The process also requires a high expenditure of resources to coordinate the different players in the supply chain. In fact, the modification of one structural component necessarily requires the adjustment of all other parts. Due to the nature of demand, driven by seasonal collections, companies are obliged to invest a considerable amount of money every year, the majority of which becomes a sunk cost at each new production. In this context a Cloud system is proposed for manufacturing districts where, each actor in the supply chain would be able to provide production capacity for components already produced in the past. This would allow to amortize the development costs reusing the vast series of components preserved over the years offering a range of items sufficiently varied to meet the creative standards of designers of new collections. The potential of the model would be in reducing production time and costs by offering a short/immediate response to new orders. Moreover, by combining components in innovative ways, modifying them a little, new shoe's structures can be developed with a significantly lower use of resources.

By developing the platform, manufacturers would undertake a process of digital transformation that would enable visibility into the processes that ensure availability of production capacity and raw materials throughout the supply chain.

12.1.1 Functioning of the platform

As explained in section 8.8 where the value chain that characterized the sector is analyzed, the companies in developing new footwear structures sometimes rely on components already processed by suppliers in the past. These components are defined as "ready" and they may only require minor modifications to fit the new shoe prototype.

The new platform would allow the suppliers to upload alle the "ready" components made for different companies during the years together with their specifications and a price range. In this way, shoe manufacturers planning to develop new models would have a wide choice of parts to choose from. The clients could use some search functions in order to select among the vast catalogue of components the ones with the characteristics (e.g. material, shape, etc.) that best fit their needs. Once that the component is selected, the client is allowed to make some limited modification among the ones proposed, that can vary from one manufacturer to another, depending on what they can guarantee (e.g., heel height and shape of the heel toe). The client can also directly contact the manufacturers for special requirements. When the modifications are confirmed, a test product is sent to the customer, who can evaluate if it fits with the prototype that is being developed and then it can decide to place the order directly on the platform.

Another key aspect of the platform would be the capability to provide visibility along the supply chain. Until now the coordination among the different actors is usually made through inefficient communication systems. The companies most of the times have to send staff members to the different suppliers to coordinate them and understand the status of progress of the works.

Leveraging on the digitalization of production processes, the idea is to enable the companies to see which manufacturers have production capacity available in order to start the prototyping phase of a new model as soon as possible. Moreover, the new technologies would allow to monitor the status of production, guaranteeing a better and easier coordination among the different stages of prototyping.

12.1.2 Prerequisites

The creation of the platform would require collaboration between the different realities of the industry, which should share and make public the specifications of past projects. Another prerequisite is the companies’ willingness to invest in digital technologies, which would certainly help to relaunch the industry, and lead it to have growth prospects for the future, instead of witnessing a reduction in demand year after year for the small artisanal realities.

The online community would be developed initially within the footwear districts, since in these areas the companies and suppliers know each other and have probably already cooperated in the past. In fact, for a company operating in the luxury footwear industry, it is essential to work with partners that can completely trust, since the maximum quality must always be guaranteed, and the production of the prototype must be completed in time for the release of the seasonal collection. Moreover, within the footwear districts the companies could be more willing to collaborate, since the people who are in charge of small or family businesses within a limited area are very likely to know each other personally. This last consideration is based on what the authors noticed during interviews with different realities of a famous footwear district as the one of Parabiago.

12.1.3 Participants

In District Cloud Manufacturing, the main actors involved are the manufacturers, the users, and the platform manager. Differently from the first two actors, the platform operator is revisited for the new model. "Italian Artisan" plays the role of Cloud Operator, acting as an intermediary between users and resource providers. However, the platform operator should be a role that represents the interests of all actors involved in the supply chain without having the ability to arbitrarily decide who to select to respond to user requests. Assocalzaturifici was therefore identified for this role: it is an Association that represents at national level the industrial enterprises operating in the footwear production sector, counting about 600 associated companies, it is the ambassador of the excellence of the Italian footwear sector. Assocalzaturifici already contributes to the affirmation of an innovative, internationalized and sustainable entrepreneurial system and articulates its activities at national and international level in multiple areas providing strategic and innovative services. It is therefore the perfect candidate to fairly represent the interests of every actor in the supply chain and can already count on a strong network of contacts to gather agreement among service providers to join the platform.

12.1.4 Characteristics of the platform

According to the literature the main requirements basing on which a Cloud Manufacturing platform can be evaluated are: the possibility to rely on a distributed resource pool; the capability to manage those resources in a centralized way; being service oriented; guaranteeing rapid elasticity and scalability; assuring a broad network access and, finally, the possibility to monitor resource usage and to evaluate the manufacturers (measured service).

Basing on the consideration made in the section 10.6.2 of the research and providing a score from 1 to 5 to the requirements described above, the authors evaluated Italian Artisan with the aim of taking it as reference point for the comparison with the new platform. The results can be seen in figure 13.

It can be immediately noticed that the requirements according to which the two platforms differ the most are the ones of “distributed service pool” and “service oriented”. For what concerns the former, the new platform would be developed with the aim of virtualizing all the resources available from the manufacturers. This feature is not always available with Italian Artisan, which is able to guarantee virtualization only partially with the “White Label” services. Instead, with regards to the latter, both of the platforms are not able to provide instant quoting mechanism engine. However, the new platform could give immediately an idea of the cost of the components, since they had been already produced in the past and, by requiring the various components form different suppliers, a sort of on-demand virtual manufacturing system is created.

Two other points in which the new platform is expected to overcome Italian Artisan are "rapid elasticity" and "measured service". The Italian start-up cannot guarantee high scalability, since the work is commissioned to a single manufacturer that relies on its network of suppliers to gather the needed components. In this situation, the production cannot be split on various manufacturers, since it is difficult that all the products will be identical and have the same level of quality. Moreover, having to coordinate all the actors involved in the production of a luxury shoe, the manufacturer requires significant amount of time when receiving new orders. On the other hand, the new platform communicates directly with the suppliers of the components, which offer simpler products that do not require complex manufacturing processes, allowing them to respond faster to demand variations. However, once a client selects the preferred item, it can be manufactured only by the supplier that uploaded that part. For what concerns the "measured service", a key objective of the new platform is to guarantee visibility along the supply chain, making it possible to monitor the status of production. However, this goal is difficult to achieve in the medium-short run, since a digital transformation of the companies composing the industry is an essential prerequisite.

A requirement in which Italian Artisan is superior to the new platform is the capability to provide a broad network access. In fact, the community of Italian Artisan includes brands, retailers and designers from all over the world as well as manufacturers coming from different parts of Italy. On the other hand, the new platform, even if it is able to guarantee coordination between the two sides, at an initial stage would probably serve to connect realities within limited areas like the footwear districts. In fact, in this particular industry it is difficult that manufacturing companies rely on supplier that cannot completely trust.

Finally, the two platform present the same level for what concerns the feature of "centralizes resource management", since both of them respect multitenancy and management of knowledge principles, but they do not provide matching algorithms to support the choice of the best manufacturer. The clients have to choose among a list of possible products or manufacturers the ones that best meet their needs.

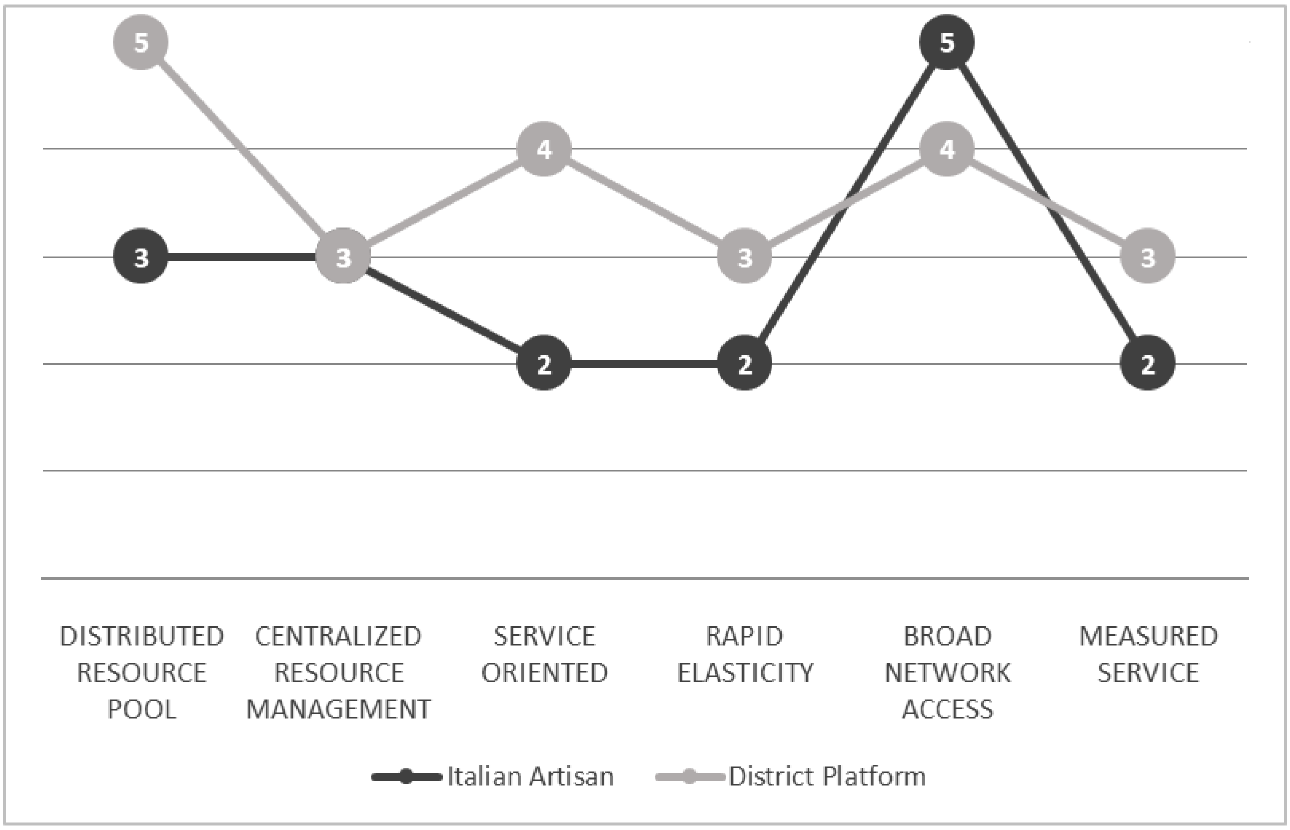

Figure 1313: Comparison between Italian Artisan and the "District CM" platform with reference to the requirements of the CM paradigm.

12.1.5 Advantages

The introduction of the new platform is expected to bring advantages not only in terms of costs, but also in terms of time, speeding up the modelling phase of a new shoe's model.

In fact, as explained in the previous sections, the platform facilitates the re-use of components already manufactured in the past, allowing companies that are interested in creating a new shoe's structure to save on the initial development costs, and suppliers to avoid investments necessary for the production of a new part (e.g., costs for the development of a mold). Moreover, another important expected benefit of the platform is the reduction of the time required for the prototyping phase of a new product, which is the key stage of the modelling phase. Basing on the interviews conducted with different realities that characterise the industry, the authors estimated that the introduction of the platform would lead to a reduction around 50% of the time needed for the development of the final prototype and, subsequently, for the creation of the samples (fig.14). This result can be achieved also thanks to the standardization of the means of communication between the different actors, that should speed-up the process.

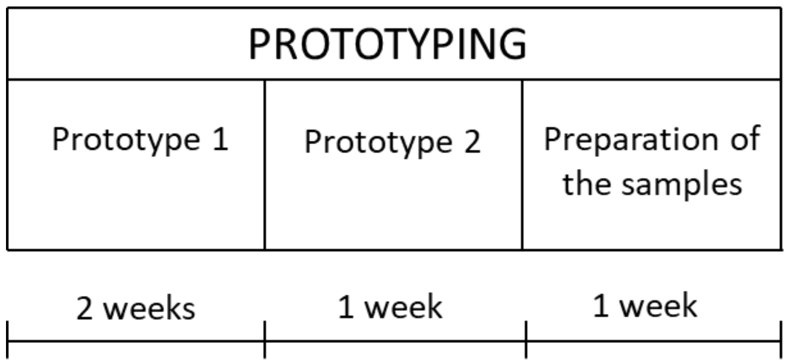

Figure 1414: reduced lead time of the prototyping phase

In addition, also the engineering phase would be accelerated, since the management of the components could be done directly on the platform, leaving the companies with the only task of creating working instructions for the eventual subcontractors. However, for what concerns the stages of design and sampling, the required timing would not be changed by the introduction of the platform. The listed benefits should encourage companies in the sector to overcome the difficulties presented by the proposed solution, which are mainly related to the willingness to invest in the digitalisation of processes and to cooperate.

12.2 Conclusion

This research constitutes the first step aimed at relaunching the artisans operating in the Italian footwear sector. As a first approach, it has been verified that Cloud Manufacturing is an increasingly relevant business model able to potentially shape the future of the manufacturing industry. The acknowledgement derives from the examination of a pool of successful Cloud Manufacturing real-world cases and by reviewing the literature of possible architectures, necessary requirements and opportunities. Subsequently, through an in-depth study of the sector and by interviewing experts and entrepreneurs, it was possible to define the footwear industry's economic outlook. The study concluded that the sector is going through a crisis and highlighted the critical aspects that afflict it as a possible turning point for its renovation. This industrial context, which is based on an intensive craftsmanship tradition and historical relationships within manufacturing districts, proved to be suitable for Cloud Manufacturing implementation. The main critical factor is the state of technological and digital advancement that makes manufacturing processes inefficient, slow, and wasteful in terms of resources (manpower, scrap, delay). Meanwhile, "major brands" have been able to modernize production and invest to involve their exclusive suppliers in the transformation process. This led to further increase the gap between artisan realities and top brands, resulting in the definitive shutdown of many companies. In this context, Italian Artisan has been the first mover towards a platform able to export the products of artisans abroad, driven by the mission of relaunching small and medium enterprises. The study carried out on its business model has shown that the platform does not present all the fundamental characteristics of the Cloud Manufacturing paradigm. However, it adequately responds to the structural needs of the industry, proposing a system that fits the needs of the sector but fails to fully exploit the potential that Cloud Manufacturing can bring. Italian Artisan proves that the Italian footwear industry is ready to move in the direction of this new manufacturing paradigm. District Cloud Manufacturing, which therefore represents an extension of the model implemented by Italian Artisan, is expected to consolidate district relations enabling the digital transformation. The new platform, having a catalogue of pre-engineered components selected by manufacturers to be produced in limited time and cost, would be able to better exploit the potential offered by the Cloud Manufacturing paradigm.

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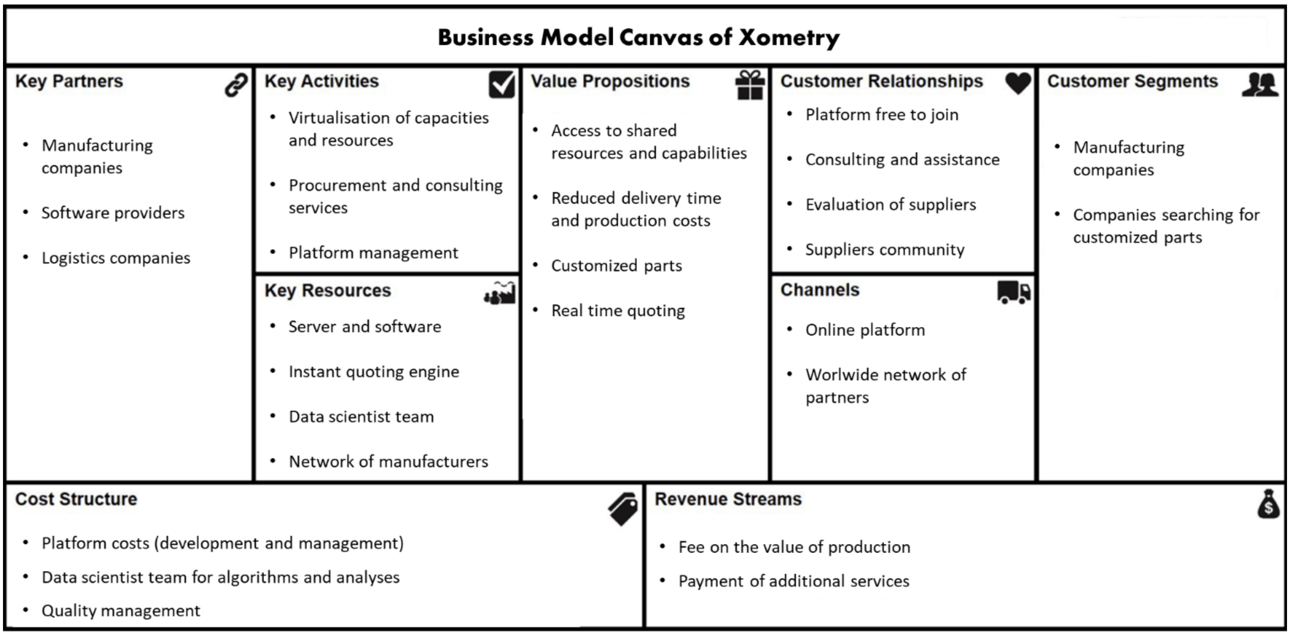
14. Appendix

14.1 Appendix A

		2000	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
COMPANIES	(Nr.)	7570	6263	6028	5804	5606	5356	5186	5031	4936	4839	4708	4505	4326	4152
EMPLOYEES	(Nr.)	113100	85918	82907	80153	80925	79254	78093	76610	77042	76744	76600	75680	74890	71882
PRODUCTION	(Million of pairs)	389,9	225,2	198,0	202,5	207,6	198,5	202,1	197,0	191,2	187,6	190,7	184,3	179,1	130,7
	(Millions of euros)	8269,3	7319,2	6468,5	6755,9	7209,6	7122,2	7472,0	7531,2	7492,6	7550,2	7797,6	7861,0	7992,3	6081,0
EXPORT	(Million of pairs)	362,4	221,8	192,3	221,4	228,9	214,2	219,8	215,0	207,6	205,9	211,1	203,2	201,4	165,2
	(Millions of euros)	6605,6	6915,0	5815,4	6611,6	7454,0	7637,7	8073,0	8389,1	8656,3	8884,0	9195,6	9585,4	10269,7	8738,6
IMPORT	(Million of pairs)	196,0	352,6	309,9	355,0	357,6	301,2	303,5	329,7	327,9	336,0	333,9	336,1	333,9	271,1
	(Millions of euros)	1796,3	3350,3	3184,1	3703,3	4067,4	3831,1	3834,4	4144,0	4526,1	4700,4	4655,1	5161,4	5362,9	4492,1
TRADE BALANCE	(Millions of euros)	4809,4	3564,7	2631,3	2908,3	3386,6	3806,6	4238,6	4245,1	4130,2	4183,6	4540,4	4424,1	4906,8	4246,5

Data taken from annual reports of Assocalzaturifici and from "Il settore calzaturiero in Italia", 2016 (45).

14.2 Appendix B



14.3 Appendix C

Business Model Canvas of Protolabs

Key Partners

- Software providers
- Logistics companies

Key Activities

- Virtualization of capacities and resources
- Procurement and consulting services
- Platform management

Key Resources

- Server and software
- Manufacturing resources
- Instant quoting engine

Value Propositions

- Access to shared resources and capabilities
- Reduced delivery time and production costs
- Customized parts
- Real time quoting

Customer Relationships

- Platform free to join
- Assistance to the client

Channels

- Online platform
- Company's website

Customer Segments

- Companies searching for customized parts

Cost Structure

- Platform costs (development and management)
- Costs associated to the manufacturing resources

Revenue Streams

- Payment of the manufactured products

14.4 Appendix D

Business Model Canvas of Italian Artisan

Key Partners

- Wink (management of the platform)
- DHL (delivery)
- Italian Manufacturers

Key Activities

- Virtualization of capacities and resources
- Procurement and consulting services
- Evaluation of the feasibility projects

Key Resources

- Server and software
- Industry Know-how
- Team of experts
- Network of Italian manufacturers

Value Propositions

- Access to shared resources and capabilities
- Reduced delivery time and production costs
- Customized shoes
- Possibility to develop a new shoe model

Customer Relationships

- Platform free to join
- Consulting and assistance to both clients and manufacturers

Channels

- Online platform
- Worldwide network of partners

Customer Segments

- International brands
- International Retailers
- Emerging designers
- Italian artisanal manufacturers

Cost Structure

- IT resources costs
- Staff costs
- Marketing Costa

Revenue Streams

- Fee on the value of production
- Payment of additional services for clients
- Subscription services for manufacturers

15. List of Figures

16. List of Tables