CUSTOMER CENTRIC INNOVATION: ADOPTION OF 3D PRINTING IN THE ITALIAN JEWELLERY SECTOR

by Elisa Martina Martinelli

Abstract

Three-dimensional printing (3D printing) is one of the customer centric innovations that characterizes the new industrial revolution. This innovation has significant implications for many companies in any sector, even the most traditional ones. The present study aims to lay the foundations for increasing and extending the knowledge on customer centric innovation and to identify the key determinants that allow that allow the adoption of a "customer centric innovation", in particular 3D printing, by business customers from the point of view of a technology provider through a conceptual framework. To achieve this purpose, a theoretical model from the literature review on customer centric innovation is identified, and then a qualitative research composed of two main steps is carried out. The first step is formed by the study of the Italian jewellery sector through an extensive desk research and meeting with experts. This permits shedding light on the role of 3D printing and dynamics of the sector, where numerous Small and Medium Enterprises (SMEs) emerged. The second step is constituted by the analysis of a case study in order to identify the determinants that allow the adoption of 3D printing by business customers from the point of view of a SME which is technology provider. The results underline that in this context the technology provider has to be able to align strategy, supply chain network, and technology under the influence of some external forces. Only this process can lead to the adoption of customer centric innovation by creating a potential and real value for business customers that does not extinguish itself with the technological potential that 3D printing already incorporates.

Keywords: *customer centric innovation, new technology adoption, 3D printing*
Jel Classification: *O32*

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1. Introduction

"Customer centric innovation" is an innovation able to provide a potential and real value for business customers that is not exhausted with the technological potential already incorporated in, but it can still meet

the current and future applications of business customers. The alignment of technological innovation with the current and potential business customers' needs is necessary, especially in a changing and uncertain world. Nowadays, in the new industrial revolution, customer centric innovations are unavoidable for technology providers operating in a business environment characterized by unprecedented turbulence, volatility, and dynamism (Christopher and Holweg, 2011; Christopher, 2016, p. 189). In this context, business customers are increasingly demanding and require more and more high-quality and ad-hoc products or services at low prices. Therefore, suppliers must seek to meet these needs through innovations that could satisfy all customers' applications (Anderson, 2012). Customer centric innovation assumes a particular meaning in a business to business context, as the collaboration is fundamental between customer and supplier. The business customer has the most knowledge about their own needs as users, while the business supplier has the knowledge to produce a solution (Von Hippel, 1986). Customer centric innovation is an innovation that can deliver results that meet or exceed market expectations (Selden and MacMillan, 2006). The most known customer centric innovation is 3D printing. This technology is even called additive manufacturing[1] (AM) (Holmström and Partanen, 2014; Gibson *et al.*, 2015; Holmström *et al.*, 2016). 3D printing has emerged during this period of great instability, thanks to its ability to create totally customized products and the availability of more affordable versions. 3D printing can be used by any company in any industry. It has revolutionized the manufacturing processes of many companies in totally different fields (Stratasys, 2016), from aerospace, automotive, and dental to more traditional fields such as jewellery (Cooper, 2015). However, both academically and managerially, there is no certainty about which factors allow the adoption of a customer centric innovation, such as 3D printing, by business customers (Bogers et al., 2016). In fact, on one hand the literature shows that most studies highlight the positive impact of a customer centric innovation on production, process especially under a general view (Marzi et al., 2018), without analysing the factors that improve the innovation itself to be adopted. On the other hand, the practice mainly underscores a recognition of only the benefits of customer centric innovation in terms of lead time reduction, resource utilization, and intrinsic end-product features, omitting to explore implementation's sources of the innovation. Even if the study considers the concept of innovation implementation as the process of alignment of the organization to provide an appropriate and committed use of the innovation (Klein and Sorra, 1996), the research is not restricted to that.

[1] Note that the terms are sometimes distinguished in business reality, a distinction avoided in this article because commonly in literature are considered as interchangeable (Gibson *et al.*, 2015; ASTM International, 2017).

In fact, the research tries to identify the key determinants of the innovation adoption for satisfying the needs of customers in order to meet the current and future applications of business customers. Business customers are considered business actors interested in adopting a 3D printer produced by the technology provider.
For this reason, the aim of the paper is to identify the determinants that allow the adoption of a "customer centric innovation", in particular 3D printing, by business customers from the point of view of a technology provider through a conceptual framework. Having this in mind, the main research question investigated is: how 3D printing can be implemented by a technology provider in order to allow its adoption by business customers? To achieve the purpose, a theoretical model from the literature review on customer centric innovation is identified. Then a qualitative constructive case study research design is carried out to evaluate the theoretical model.

The context of analysis is the jewellery sector, where the 3D printing is effectively used for production (Zollo *et al.*, 2016) and it enjoys a high profile worldwide (Carrigan *et al.*, 2017). Italy provides the geographical context as it is one of the world-leading jewellery sector (Italian Exhibition Group SpA, 2017) and due to its internal changes. In fact, it is recognized that, aside from few big international companies that import 3D printers in Italy, numerous Small Medium Enterprises (SMEs) have emerged in order to deliver both services and products aligned with the characteristics of 3D printing. In the jewellery sector is particular difficult gaining access to specific information due to the secrecy and security involved, and the topic is a sensitive one for informants to discuss (Carrigan *et al.*, 2017). For this reason, to conduct the investigation, triangulation of different sources is used to ensure construct validity.

This study seeks to contribute to the academia by the knowledge creation about customer centric innovation and in particular of 3D printing, providing a conceptual framework. The research is even addressed to practitioners who aim to meet business customers' needs and applications, suggesting the main determinants to consider for an innovation's adoption, especially 3D printing.

This paper is structured as follows. In Section 2 we review the literature on customer centric innovation, focusing on 3D printing, and then we present the theoretical model.

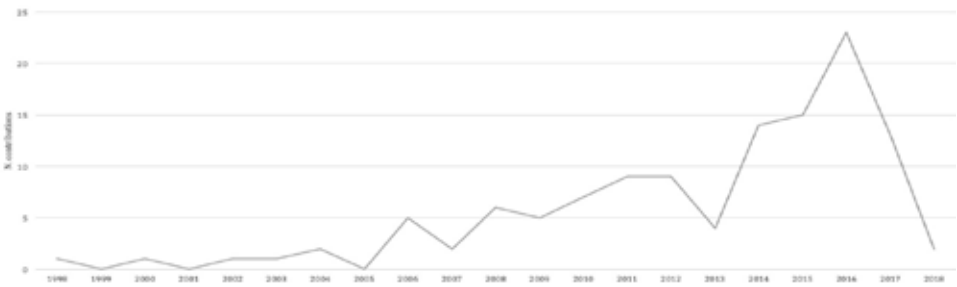
Sections 4 and 5 highlight the analysis and discussion of the findings, respectively. Section 6 provides limitations, implications and conclusions to the paper.

2. Literature review: a theoretical model

2.1. Literature review

Only a few authors have examined customer centric innovation in the literature. This paper considered the definition of a customer centric innovation concept given by Selden and MacMillan (2006, p. 1): "a process for making innovation deliver results that meet or exceed market expectations". We decided to conduct an analysis of the literature. In the first step, we identified the keywords by literature background. The used query included the keywords "customer centric*" and "innovation" linked by the Boolean operator AND, recollected to both the abstract and main text sections. The time period was not selected according to highlight the number of publications per year. We used ISI Web of Knowledge[2] and AB Inform Complete[3] as they are the most integrated sources for this type of research, where it is possible utilize a query. From the research, only 126 peer-reviewed papers were identified (62 from AB Inform Complete and 77 from ISI Web of Knowledge). By a first screening excluding duplicate results, we collected a total of 119 contributions related to customer centric innovation, spread over the years 1998 to 2018[4]. As shown in Fig.1, the number of publications regarding customer centric innovation is low, but increases to 14 in 2014, 15 in 2015, and 23 in 2016.

Fig.1: Number of contributions per year

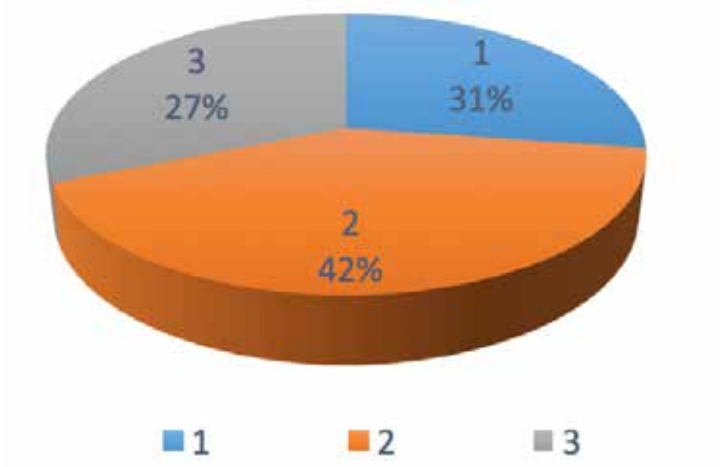


Source: own elaboration

[2] www.webofknowledge.com/
[3] https://search.proquest.com/abicomplete/advanced
[4] The analysis has been updated to April 2018

In light of academics' increased interest, an analysis of literature was conducted in order to identify the main areas to which determinants of the implementation of customer centric innovation belonged. According to et al. (2003) "Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review* Introduction: the need for an evidence- informed approach", "type" : "article-journal", "volume" : "14" }, "uris" : ["http://www.mendeley.com/documents/?uuid=66d88828-7ec7-3c31-b9c3-521498a76be7"] }], "mendeley" : { "formattedCitation" : "(Tranfield, Denyer, & Smart, 2003, the aim of an analysis of literature is to provide collective insights through theoretical synthesis into fields and sub-fields. A second screening made it possible to exclude off-topic contributions. Among the database of 119 contributions, 77 significant works were considered useful of our purpose. The result was a fragmented analysis of possible determinants for the implementation of customer centric innovation, without providing a holistic vision. Three main clusters of determinants that the technological provider can use emerged. They were selected as the most studied and investigated areas of research to which single determinants can be attributed. The first cluster relates to technological enablers of the customer centric innovation. The second regards the constitution of a business model and internal strategy to support the customer centric innovation. The last concerns the creation of a more suitable network of relationships for developing the customer centric innovation. Fig.2 presents the three clusters.

Fig.2: Three clusters of determinants for the implementation of a customer centric innovation



Source: own elaboration

Tab.1: Three clusters of determinants and respective theme and examples of contributions

Cluster	Theme	Examples of contributions
1 Cluster	Technological enablers of the customer centric innovation	Palacios-Marques *et al.* (2016); Soeiro and Santos (2015); Lee and AbuAli (2011); Johannessen and Olsen (2010); Kohler *et al.* (2009); Selden and MacMillan (2006)
2 Cluster	Constitution of a business model and internal strategy to support the customer centric innovation	Schneckenberg *et al.* (2017); Leavy (2017); Hoeber and Schaarschmidt (2017); Sabatino (2016); Osakwe (2016); Price and Wrigley (2016)
3 Cluster	Suitable network of relationships for developing the customer centric innovation	Vetterli et al. (2016); Jia et al. (2016); Sindakis et al. (2015); Tax et al. (2013); Romero and Molina (2011); Wagner and Majchrzak (2006)

Source: own elaboration

To address the need for a holistic vision underscored by the fragmented contributions, the present study firstly proposes a theoretical model from the literature review on customer centric innovation (explaining in detail each of the previous presented three clusters, Tab.1) and then tests and assesses it on empirical case data. In the next section, the holistic interpretative model is described in detail.

2.2. Theoretical model

The most recent research approaching the purpose of the present paper is that of Mellor et al. (2014), which—like the majority of the literature—analyses the implementation of AM only as an enabler of the production process. This specific contribution is extremely valuable as a conceptual categorization tool for the determinants of the 3D printing product adoption. The work of of Mellor et al. (2014) highlights three main determinants and some external forces. Main determinants that emerge are characteristics of the technology to implement, the internal strategy of the technology provider and involved supply chain network. External forces are the evolution of the reference sector, evolution of the considered technology, and influence of the adjacent sectors.

Starting from this main conceptual categorization tool, we provide a theoretical model that considers last advancements pointed out in the literature review. The following sections examine determinants and external forces.

2.2.1. Technology

The first determinant to be considered is the characteristics of AM technology that the provider wants to implement in order to allow its adoption by business customers. A company that decides to move in this direction must be aware of three main elements: the evolutionary level achieved by the innovation, the typology, the limitations, and the process of qualifying materials. In terms of the first element, Foster (1986) emphasizes that it is of utmost importance for manufacturing companies, especially in traditional sectors, to understand the evolving stage of a technology in order to program its development (S-curve). The technology provider has to recognize the suitable phase—embryonic, growth, maturity, or aging—for investment in the development of the technology (e.g., hours worked, budget allocated, researchers employed) (Taylor and Taylor, 2012).

Second, technological advancements in AM, as well as the discovery of new applications of the technology, are still in development, and knowledge of the typologies and disadvantages is fundamental. The first usage of AM, the rapid prototyping process, occurred in the 1980s. Using this method, it became possible to produce rough physical prototypes of the final product used for theoretical studies (Gibson *et al*., 2015). The technology then went through a significant evolution until the 3D printing that we know today, allowing for the direct production of the final objects. The materials used may be different (aluminium, super alloys, stainless steel, titanium, polymers, ceramics, etc.) according to the technique employed, including extrusion, wire, granule, bed of dust and inkjet heads, laminates, and polymerization through light. Stereolithography (SL) belongs to the last category of techniques and was patented by Chuck Hull in 1986. Initially, SL was used only by professional customers; today it can be bought and employed by everyone. Even if the advantages of AM technologies are well understood, the limitations are not. The latter includes place restrictions due to the size of objects that can be manufactured, cost of the printing equipment, and regulations and government interventions delimit who can perform 3D printing and what can be printed (Attaran, 2017). For this reason, the technology provider has to be aware of what technology can be implemented. Technology-enabled innovation is more meaningful organizationally when viewed as a service (Chew, 2016), which is defined as a value co-creating process combining the technical with user competences (Gallouj and Weinstein, 1997). In particular, AM enables customers to co-design products that perfectly fit their demand (Weller *et al.*, 2015). Finally, materials are constantly subjected to a solid qualification process. Its characteristics are a critical aspect of design and production that influence the resulting microstructure based on the processing parameter according to material properties (Petrick and Simpson, 2013). For this reason, this process is a sensitive step in technology implementation.

2.2.2. Company strategy

According to the implementation of a specific technology, the decisions of a technology provider must be coherent and respectful of its internal strategy. Gatignon and Xuereb (1997) underscore the fundamental role of strategic orientation in a company for supporting the development of an innovation. In fact, the failure of either an implementation or the innovation itself can reflect an organization's failure (Klein and Sorra, 1996). In particular, the alignment of business, manufacturing, and R&D is an unavoidable element (Gupta *et al.*, 1986). The technology benefits must be linked to the capabilities required of the manufacturing unit and capabilities derived from the business strategy, viewed as the market-pull strategy to innovation implementation (Mellor et al., 2014).

This second main determinant has some implications for organizational and operational factors. On the organizational side, the main characteristics that must be considered for the implementation of a technology are company size, organizational structure, workforce, and corporate culture. Aragón-Correa et al. (2007) highlight how a learning mechanism that is shared at an organizational level could have a direct impact on the innovation implementation. It requires a reorganization around customers and a change in the company mind-set, conceptual approach, capabilities, and organization (Nobre, 2011; Hoeber and Schaarschmidt, 2017). In fact, customer centricity is defined as a strategy focused on the customer's applications and organizing the future actions according to the customer's priorities (Sabatino, 2016). Meanwhile, on the operational side, processes' integration, planning, quality control, and accounting are the main elements for supporting the development of a technology innovation. Highly integrated solutions are needed as a function of concentrated problem exploration (Price and Wrigley, 2016) and, in order to create and gain value, the company has to actively integrate customers into its product or service development process (Lagrosen, 2005; Denning, 2013).

2.2.3. Supply chain management

The third determinant concerns supply chain management. In fact, digital manufacturing is certainly the first technology that contributes to the transformation of logistics and supply chain management (Gligor and Holcomb, 2012) and its implementation into the relational network.

The literature demonstrated the increased attention on technologies that have promise for tomorrow's supply chains (Stevens and Johnson, 2016) and the democratization of product and process knowledge (Anderson, 2012). These include AM technologies such as 3D printing (Brennan *et al.*, 2015). Considering 3D printing in detail, Holmström and Partanen (2014)

point out that the implications of supply chain management and logistics are fundamental, yet such a topic has received little attention in either the literature or practice (Christopher and Holweg, 2011). Flint et al. (2008) argue that supply chain management and logistics management involve designing, managing, and improving product and service innovations in attempts to serve downstream customers' and ultimately end-use customers' ever-changing needs and expectations to help create superior value for and with them over time. This requires a deep understanding of all the relationships involved and the selection of the most suitable network to support the technology implementation. Customers and suppliers must be integrated into the innovation development process in order to reduce time to market and satisfy customers' applications (Lambert and Cooper, 2000). In addition, interactions between stakeholders and customers in the delivery of innovative services and practices have a fundamental role (Sindakis *et al.*, 2015) supported by a virtual environment characterized by information sharing (Romero and Molina, 2011; Shani *et al.*, 2003).

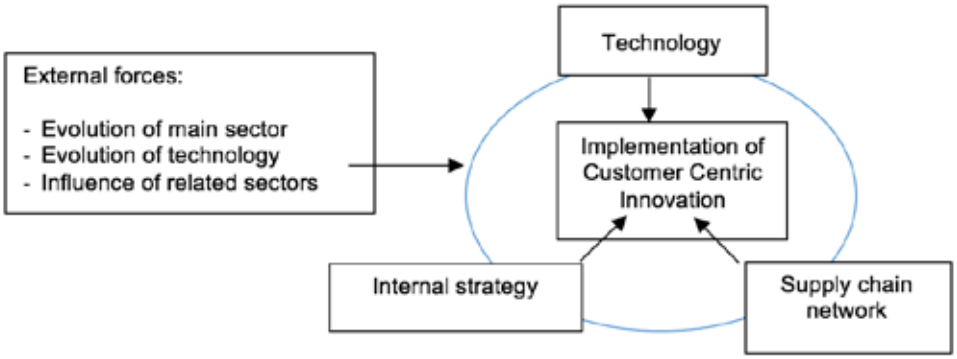
Thus far, this paper has identified the three main determinants that a technology provider has to assess in order to allow the adoption of 3D printing by business customers.

2.2.4. External forces

The analysis of external forces identifies three additional factors. The first external force is the evolution of the reference sector. The primary sector of the technology provider affects its choices in the optics of industrial marketing (Souder *et al.*,1998). In fact, innovation-oriented business choices must take into account competitive pressures and consumer needs (Anderson, 2012). The second element that influences corporate decisions is the evolving stage reached by technology (Zhou *et al.*, 2005), which reflects the information transmitted to all actors involved and makes the choice of innovation type more consistent with business goals. Finally, the third external force that orientates the strategic choices of the producer is the evolution of neighbouring sectors. New consumers and users of technology can change business decisions, as 3D printing is an innovation that can be used in any domain (3D System, 2016; Stratasys, 2016).

By this analysis, a theoretical model can be identified (Fig.3).

Fig.3: Theoretical model for implementation of customer centric innovation



Source: own elaboration from Mellor et al. (2014)

Using this theoretical model, the present research analyses in detail the identified determinants for 3D printing adoption by a case study of a SME leading technology provider in the Italian jewellery sector. This work will help understand the influence between the main determinants and external forces (Bogers *et al.*, 2016). In particular, the theoretical model can be tested by practical evidence in order to discover the limiting conditions of applicability (Whetten, 1989).

3. Research methodology

The study was part of a wider research conducted on the impact of DDM technologies on innovative companies and their own network (Martinelli, 2018). The following paragraphs describe the characteristics of the research methodology applied. Research design, case selection and data collection are presented.

3.1. Research design

The research process is composed of two main steps. The first step is formed by the study of the sector through an extensive desk research and meeting with experts, shedding light on the role of 3D printing and dynamics of the sector characterised by numerous new SMEs. In particular, three main SMEs that operate in the Italian jewellery sector were interviewed. The second step is constituted by the analysis of a case study in order to identify the determinants that allow the adoption of 3D printing by business customers from the point of view of a technology provider.

This choice is justified by some considerations. First, the qualitative ap-

proach is appropriate for industry investigations (Ellram, 1996; Yin, 2013), particularly for industrial marketing research that shows a dominance of case research (Piekkari *et al.*, 2010). Second, the case study approach is generally recommended for theory building (Yin, 1989; Ridder, 2017); in fact, it is "suitable for illuminating and extending relationships and logic among constructs" (Eisenhardt and Graebner, 2007, p. 27) rather than aiming to represent firms' population (Eisenhardt and Graebner, 2007). Finally, a single case study design is appropriate for network research in many situations due to the specific characteristics of the subject analysed (Meredith, 1998; Yin, 2003) in exemplar and revelatory organisations (McCutcheon and Meredith, 1993). It provides the opportunity to open a black box arises by looking at deeper causes of the phenomenon (Ridder, 2017). Its strength is in creating theory by expanding construct and relationships within distinct settings (Ridder, 2017), without attempting to achieve a statistical generalization or generalization of the results to other populations (Yin, 2003). Validity and reliability of the research findings are supported by various practices, as shown in Tab.2.

Tab.2: Methodological rigor of the research

Internal validity *(logical validity)*	**Construct validity** *(quality of conceptualization or operationalization of the relevant concept)*	**External validity** *(generalizability)*	**Reliability** *(correctness of operational and research procedures)*
Theoretical framework explicitly derived from the literature Research framework explicitly derived from the literature Pattern matching Theory triangulation	Data triangulation: Extensive desk research Meeting with experts Case study analysis Review of draft by peers Clear chain of evidence Indication of data collection circumstances Explanation of data analysis	Rationale for case study selection Details on case study context Cross company analysis *(meeting with experts)*	Case study protocol Case study database Organization's actual name given

Source: own elaboration from Cook and Campbell (1979), Yin (1984), Gibbert et al. (2008)

3.2. Customer centric innovation and case selection

This work is focused on the analysis of customer centric innovation, in particular 3D printing. The research is conducted by meeting with experts in order to shed light on sectors' dynamics and technology, and a case study. Selection of 3D printing is due to its characteristics. The majority of existing studies on 3D printing focus on the implementation of process by its introduction in the production. Today there is used not just for prototyping, but

also tool-making and low-volume manufacturing across industry sectors (Holmström et al., 2016). This is strengthened by all commonly recognized advantages of 3D printing (Marzi *et al.*, 2018) and its identification as an enabler for major profits (Gibson *et al.*, 2015; Bogers *et al.*, 2016; Jia *et al.*, 2016). In fact, AM—3D printing—has deeply contributed to the transformation of logistics and supply chain management (Gligor and Holcomb, 2012), and its introduction in a company implies an improvement of the production process supporting traditional manufacturing rather than replacing it (Rylands *et al.*, 2016) and generating savings in terms of lead times and resource utilization (unlike common subtracting processes) (Holmström and Partanen, 2014). 3D printing is an innovation whereby the final product is built using a layer-by-layer basis, starting from the 3D design of the object (computer aided design [CAD]) (Berman, 2012). The most relevant benefits of this technology are the possibility of creating directly finished products by eliminating many intermediate production phases (Holmström and Partanen, 2014), the ability to realize complex geometries that would otherwise not be generated (Sasson and Johnson, 2016), and the production of more homogeneous, robust, and lighter-finished products (Berman, 2012). The new forms of innovation are based on an intimate understanding of the customer (Crosby and Johnson, 2006), resulting in three main benefits: an inimitable offer, a closer link with the customer, and additional knowledge about the technology (Selden and MacMillan, 2006). Yet even if these advantages of 3D printing are commonly recognized, the determinants of the implementation of this customer centric innovation in order to allow its adoption by business customers are still unclear. In fact, there is no certainty about which factors allow 3D printing implementation by a technology provider in order to meet business customers' applications.

The chosen jewellery industry—as work of Ryan et al. (2017) underlines—is a craft business described as an area of "white space", which presents a range for future research opportunities. In fact, from a managerial perspective, identifying different business models and the range of product and services offered would show how such operations complement the more "industrial" players in the market (Rogers *et al.*, 2016). In addition, all parts of jewellery industry supply and value chains, and especially design and manufacturing, now need to become aware of how disruptive and unsettling 3D printing introduction has the potential to become (Cooper, 2016) and what are its characteristics. The jewellery industry is suitable for this research as the 3D printing is not only used for prototyping, but even for production (Zollo et al., 2016). It enjoys a high profile worldwide (Carrigan et al., 2017) and Italy provided the geographical context as it is one of the world-leading jewellery sectors (Italian Exhibition Group SpA, 2017) and due to its changes. Aside from few big international companies that import 3D printers in Italy, numerous SMEs have emerged.

Regarding the case study, the analysed technology provider is an Italian SME founded in 2007 in Vicenza—renamed in this study Company Alfa in order to preserve the anonymity of the actual company—that produces 3D printers for prototyping and rapid manufacturing, materials for 3D printing and related management software. The characteristics of this SME satisfy the significance requirements of case selection. In fact, it is featured by quality and continuous innovation and has filed more than 250 industrial, technological, and design patents since 2007. The professional 3D printer manufacturer was chosen as, thanks to its unique features, enabled the development of technology over the years in one of the most traditional and typical handicraft-oriented Italian sectors. The R&D department's research into not only 3D printers, but also photosensitive materials and management software for 3D printing, allowing a continuous evolution. It represents a significant and revelatory organisation (McCutcheon and Meredith, 1993), able to shed light on the determinants of 3D printing implementation and adoption. An example is a special printer that won the award for the category "Personal 3D Printer of the year".

3.3. Data collection

The jewellery sector is a particularly difficult industry to gain access to due to the secrecy and security involved, and the topic is a sensitive one for informants to discuss (Carrigan *et al.*, 2017).

This presents particular difficulties as unsolicited approaches to businesses are likely to be rejected. For this reason, to conduct the investigation, triangulation of different sources is used to ensure construct validity. Using multiple data types helps to mitigate social-desirability bias, single-informant bias and the bias of the individual researcher, such as a priori belief (Reuter et al., 2010). As shown in Fig.4, the process was composed by two main steps.

Fig.4: First and second steps of data collection

FIRST STEP	
Sources	**Outcome**
a) Extensive desk research *Conference proceedings, paper, business reports, etc.*	• Deep comprehension of actual theoretical and managerial context
b) Meeting with experts *Semi-structured interviews*	• Gained information about dynamics of the specific sector • Test the interview protocol

→

SECOND STEP	
Sources	**Outcome**
Analysis of the case study	• Elaboration of the final interview protocol • Data acquisition on the case study

Source: own elaboration

In the first step, an extensive data collection was carried out through desk research. Information derived from scientific journals, conference proceedings, company presentations, business reports, and industry analyses were examined. This secondary data generated a deep comprehension of the actual theoretical and managerial contexts on the research subject. In order to gain information about the main dynamics and networks of the specific sector shedding light on the role of 3D printing, data were collected by meeting with experts. In particular, three main SMEs that operate in the Italian jewellery sector were interviewed. The identification of participants was conducted by a mixed and emergent sampling strategy incorporating both purposive and snowball approaches (Crouch and McKenzie, 2006). In particular, the selected companies must be respectful of being:

- both supply (products or services) and distribution companies belonging to the sector;
- the most active companies, especially in annual trade fairs (i.e., Baselworld 2016[5], Smau 2016[6], Technology Hub 2017[7]), which are the most important tools for actors operating in this sector; and
- the most active companies on social websites, on the internet, and in specialized journals.

An approximately 90-minute semi-structured interview was conducted verbally with the respective managers, CEO or owners of the chosen companies. All interviews were taped and transcribed to address issues of credibility and confirmability (Lincoln and Guba, 1985). The participating SMEs' identities were anonymised using capital letters (A, B, C – as in Tab.3).

Tab.3: Companies and respective interviewees

Company	Typology	Interviewee's role
Company A	Distributor	Chief executive officer
Company B	Supplier	Chief executive officer
Company C	Supplier	Owner and Chief executive officer

Source: own elaboration

This small number of participants is consistent with prescribed methodological approaches to explore the sector (Crouch and McKenzie, 2006) as these selected participants introduce and reflect on issues that they perceived as relevant to the research topic (Kvale, 1996), presenting the situation of SMEs that have emerged in order to deliver the best solutions for business customers.

During the second step, the structure for analysis of the case study was created. The meeting with experts and theoretical researchers' frameworks

allowed to test the final interview protocol. The structure of the interview was composed of four main sections:

- company characteristics and activities;
- new technologies;
- supply chain network (sub-sections of customers, suppliers, and intermediaries);
- future perspectives.

The semi-structured interview was conducted with the Area Manager Italia of Company Alfa that is the SME selected as case study.

In the following sections, the analysis of the main sector and the case study are presented.

4. Analysis

According to the aim of this paper the following sections present the description of the characteristics of the main sector using desk analysis and meeting with experts, and the analysis of the case study. The next first and second sections are respectively the first and second steps of *Research methodology*.

4.1. Sector description

In 2016, the world-leading Italian jewellery sector recorded revenues of approximately 7.8 billion euros as well as a drop in jewellery and bijoux sales (4.6%) and precious jewellery (3.5%), mainly due to the entry of China and India into the market (Italian Exhibition Group SpA, 2017). These changes related to business to consumer context occurred at the same time of an initial evolution of business to business technology providers' sector that, from typical handicrafts, has seen the introduction of AM. As underlined in the work of Zollo et al. (2016) that considers the district of Arezzo, most of SMEs have introduced the 3D printing in the productive process

[5] https://www.baselworld.com/en-US.aspx
[6] https://www.smau.it/milano16/
[7] http://www.technologyhub.it/en/

without its externalization. 3D printing confirmed companies already active in the industry and enabled the entry of new realities, including both manufacturers of printers and service providers. Actors such as designers, virtual designers, and engineers have emerged as new professional figures (Versteeg *et al.*, 2016). This situation is particularly evident according to the three companies interviewed during the first step of the analysis (Tab.4).

Tab.4: Companies interviewed during first step of analysis

Company	Typology	Description
Company A	Distributor of 3D printers	Company active in the electronic-industrial sector since 1972 in Milan. It deals with exclusive distribution for Italy of four leading companies in their respective sectors. Through a network of agents and technicians operating across the country.
Company B	Supplier of 3D printing software and solutions	Since 2012 service company for CAD design, rapid prototyping and protofusion based in Valenza specialized in the realization of 3D jewellery prototypes. It designs and manufactures prototypes for high jewellery products with the latest generation technology.
Company C	Supplier of 3D printing software and solutions	Producer company based in Vicenza, originally part of another company since'86. In 2014, it becomes professional supplier of 3D printing software, photo-realistic rendering, 3D printer, rapid prototyping, metal and plastic sintering, 3D digital scanning, reverse engineering.

Source: own elaboration

The business environment in the jewellery sector has changed. In the last five years, aside from few big international companies that import 3D printers in Italy, numerous SMEs have emerged in order to deliver both services (software, development of designs, programming, etc.) and products (creation of 3D printers or direct final objects) aligned with the characteristics of 3D printing. This is due to an interest in new technologies, the limited information, and a substantial diffusion of low-cost 3D printers. The most successful companies are those that established entry barriers, such as patents, unique materials, and exclusive techniques, in order to generate competitive pressure for others. This condition is quite complex to create for the different and continuous influences from adjacent sectors, especially dental and medical sectors. The following section analyses a case study of a SME that is a technology provider who reached this phase.

4.2. Case study

An invention becomes an innovation when it is successfully commercialized (Brem et al., 2016). A company that reached this particular situation in the jewellery sector is Company Alfa. Founded in 2007 in Vicenza, this SME has seized the opportunities made available by the new 3D print-

ing technology. The professional 3D printer manufacturer, thanks to its unique features, enabled the development of technology over the years in one of the most traditional and typical handicraft-oriented Italian sectors, becoming one of the most important providers of this technology that have their plants in Italy. By following the interview protocol, we could identify and analyse the main relevant aspects summarized in Tab.5 and presented in the following paragraphs.

Tab.5: Emerging aspects from the interview protocol

Section	Aspects
Company characteristics and activities	• Focused on R&D; • Vertically integrated; • Core focused on technological know-how; • 16% of turnover invested in technological innovation; • Internal development of 3D printer features, search for new materials, assembly, software and creation of technical features of particular parts; • Highly coordinated and integrated system of operation with R&D section of quality control unit.
New technologies	• Stereolithography; • 30 international patents; • 20-year management experience in the industry.
Supply chain network	• Mainly local suppliers; • Direct link with end customers (when the role requires it) or distributors (agents or distribution brokers); • Reconsidered network of relationships according to main business customer needs.
Future perspectives	• Evolution of main sector: o change in competitive environment; o new uses of 3D Printing. • Natural evolution of technology: o information; o different techniques. • Evolution of related sectors: o needs of actual consumers; o new customers.

Source: own elaboration

First, the SME has a strong orientation focused on research and development. Its organizational structure is vertically integrated, and the core of the company focuses on technological know-how. Half of the human resources (around 18 people) are dedicated to R&D, and approximately 16% of annual revenues on average is invested in technological innovation.

The innovation is represented by the development of 3D printer features and the search for new materials (in the range of 55; it is one of the largest manufacturers worldwide). The production of hardware components is given on a third-party basis according to specifications, while assembly, software, and the creation of the technical features of particular parts (e.g., laser) are developed internally. A highly coordinated and integrated system of operation is used with the research and development section of the quality control unit. These strategic choices allow the SME to focus on the implementation of innovation in order to meet the most specific demands of current and potential business customers and to make it the main goal to further orient all subsequent business decisions.

According to the second area of analysis, new technologies, Company Alfa uses stereolithography instead of the widespread lost-wax casting process. The 3D printing industry is shifting from the technology introduction stage to maturity because of the expiration of some patents that have allowed the dissemination of knowledge among the actors. To date, Company Alfa has more than 30 international patents and a 20-year management experience in the industry. Such features have created a unique current and potential value for adoption by business customer that can be difficult to match.

Regarding the supply chain involved, the third section of the review protocol, Company Alfa mainly uses local suppliers and relies either directly on end customers (when the role requires it) or on distributors that can be distinguished as agents or distribution brokers. 3D printing led the SME to reconsider the network of relationships by catalysing attention to increasingly demanding business customers.

In the last section of the review protocol, some external forces emerged. The SME witnessed the emergence of increasingly demanding business customers (with increasing interest from traditional and non-traders), leading to the modification of product range by developing typologies of economically affordable printers without sacrificing machine quality. In order to be able to develop innovative technology respecting consumers' applications, the company first included the evolving dynamics of the sector. The change in the competitive environment, due to the entry of non-existent jewellery companies historically (but in any case producing printers or service providers), prompted Company Alfa to rethink the relationship network and internal strategy, thereby allowing for the expansion and contamination of techniques, making 3D printing available for new uses.

Second, the natural evolution of technology has come about in terms of disseminated information among actors and various techniques used by companies. Since 3D printing is an innovation that is being discussed a lot, the information available is typically transmitted by accredited bodies (such as institutions, universities, and research centres) or through social media. The latter source often incorrectly exasperates a strong expectation of 3D printing, seen as an instant revolution in manufacturing processes. This results in a distortion of real possibilities and characteristics of innovation, which is instead subject to a natural process of development and growth alongside traditional manufacturing techniques over the years (R&D). Company Alfa participated in many conferences and events as an opinion leader in order to share real information on innovation. With regard to the various technologies, the evolution of 3D printing offers companies a wide range of different techniques. The choice made by Company Alfa reflects a precise internal strategy contextualized in a traditional industry.

Finally, this innovation is constantly subject to influences from adjacent sectors to the required technical specifications, such as the dental field.

This allows for the continuous updating of the materials used, the quality standards and the required precision, meeting the needs of application of current consumers and attracting new ones.

5. Discussion

This work aims to build upon the extant literature proposing, testing and assessing a theoretical model from the literature review on customer centric innovation. Using the model, this study investigates in detail the identified determinants and external forces for the implementation and adoption of 3D printing by two steps: analysis of the sector and analysis of the case study.

The findings suggest that in the Italian jewellery sector the most successful companies are those that established entry barriers, such as patents, unique materials, and exclusive techniques, generating competitive pressure for others. In particular, it is recognized that numerous SMEs started to deliver both services (software, development of designs, programming, etc.) and products (creation of 3D printers or direct final objects) aligned with the characteristics of 3D printing. This is due to an interest in new technologies, the limited information, and a substantial diffusion of low-cost 3D printers. By the analysis it emerges that the three areas of studies identified through the theoretical model are recognized as relevant by the technology provider. They are characteristics of technology to implement, supply chain network, and internal strategy of technology provider. In addition, the case study shows by practical evidence the undertaken decisions

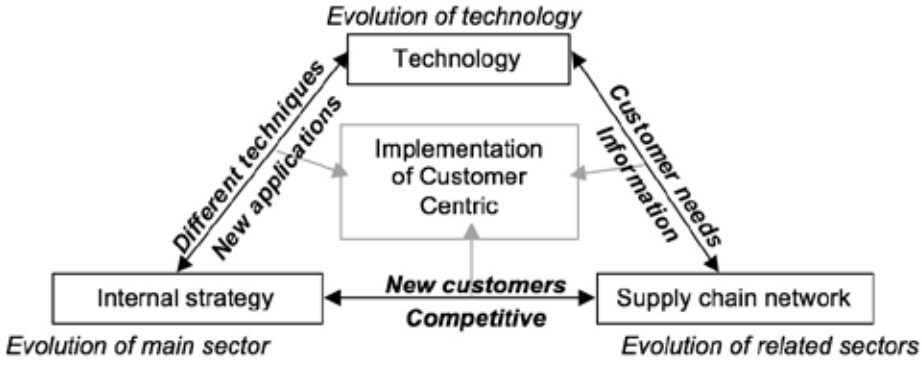
and activities in order to implement and adopt the 3D printing innovation.

However, the results indicate additional nuances that had not yet been captured by the literature.

In fact, from the constructive case study research emerges that only the alignment of the three main determinants leads to the implementation of the customer centric innovation.

In addition, this analysis helps to understand in details the causal relationship between the main determinants and external forces (Bogers *et al.*, 2016). Differently from the original theoretical model, the three main external forces have a significant impact on the main factors, as shown in Fig.5. In the practice emerged that evolution of the reference sector, evolution of the considered technology, and influence of the adjacent sectors have an impact respectively on internal strategy of technology provider, characteristics of technology to implement and supply chain network.

Fig.5: Conceptual framework for implementation of customer centric innovation



Source: own elaboration from Mellor et al. (2014)

In particular, according to the evolution of the main sector, the technology provider should choose its strategic internal decisions in order to answer to increased competitive pressure by modifying network relationships and to react to applications in new fields by modifying technology characteristics. Regarding the evolution of technology, the manufacturer could develop the technology in accordance with a correct information transmission to all involved actors and in agreement with an informed choice of innovation type more consistent with business goals. Concerning the evolution of related sectors, the technology provider should operate with business partners able to support the technology implementation. The recognition by business customers of the additional value proposed by the technology provider thanks to the new technology and its network of

suppliers is fundamental. In fact, the mission of the main company has to enable businesses to embrace the digitalisation and facilitate final users to become innovative and competitive, reducing production times and developing original new products. This is particularly linked to characteristics of specific fields of application, that influence the main technology.

In conclusion, the only alignment of the three major factors under the influence of external forces leads to an implementation of the customer centric innovation directed at both actual and potential business customers. The value created is a present and potential value that differs from the pure technological potential that 3D printing already incorporates, but takes into account many factors that determine its characteristics, meeting the current and future needs of application of business consumers.

6. Conclusion

3D printing is one customer centric innovation that characterizes the new industrial revolution. Its advantages are well-known when it is used to improve a production process, but it is unclear what determinants allow its adoption by business customers from the point of view of a technology provider.

This study defines a theoretical model that emerged from the literature review, tests it on empirical case data and finally provides a conceptual framework in order to contribute to prior research. The analysis, built on constructive case study research design (Yin, 2003), highlights the need for alignment among the three major determinants, under the influence of some external forces. Only this process can lead to the adoption of customer centric innovation by creating a potential and real value for business customers that does not extinguish itself with the technological potential that 3D printing already incorporates. This contribution shows how it is possible to operate in an environment characterized by extremely demanding business consumers by providing a solution that it is aligned with the increasing need of innovation emerged in a traditional industry. Italy has provided the geographical context where study this situation due to its recent changes. Aside from few big international companies that import 3D printers in Italy, nowadays numerous SMEs have emerged to deliver both services and products aligned with the characteristics of 3D printing.

One limitation of the research is that it is a small-scale study of a single company in one industry and conducted in a specific geographic cluster. Cross-industry validation studies would generate further insights. In particular, further studies could explore the comparison of the adoption of 3D printing between different sectors. Another constraint is the analysis focused only on a product provider; future lines of research can explore the interpretative model for service providers. In addition, the limited ex-

planation of the literature review could be improved by further theoretical research based on an extended deep analysis of the three clusters.

This study has some theoretical and managerial implications.

Even if the case study does not attempt to achieve statistical generalization (Yin, 2003), it generalizes the finding to contribute to the creation of theory. In fact, this research contributes to the understanding of customer centric innovation and, in particular, sheds light on the main elements affecting 3D printing adoption, providing a conceptual framework.

On the managerial side, the most relevant implication relates to the possibility of the usage of this conceptual framework by managers who want to adopt a customer centric innovation considering all aspects that could prevent the satisfaction of current and future applications of business customers. The aspects involved are technology characteristics, internal strategy, and supply chain network under the influence of the evolution of the main sector, the technology, and the adjacent sectors.

Elisa Martina Martinelli
Catholic University, Milan, Italy
elisamartina.martinelli@unicatt.it

Riassunto

La stampa tridimensionale (stampa 3D) è una delle innovazioni incentrate sul cliente che caratterizza la nuova rivoluzione industriale. Quest'innovazione ha implicazioni significative per molte aziende che operano in settori diversi, anche quelli più tradizionali. Il presente studio ha l'obiettivo di porre le basi per approfondire la conoscenza in tema di innovazione incentrata sul cliente e di individuare i fattori che consentono l'adozione di tale innovazione, in particolare la stampa 3D, da parte di clienti business dal punto di vista di un fornitore di tecnologia. Per raggiungere questo scopo viene prima identificato un modello teorico dall'analisi della letteratura e successivamente viene condotta una ricerca qualitativa composta da due fasi principali. La prima fase consta nello studio del settore della gioielleria italiana attraverso una vasta ricerca documentaria e incontri con esperti. Ciò ha permesso di far luce sul ruolo della stampa 3D e sulle dinamiche di settore, in un contesto in cui sono emerse numerose Piccole e Medie Imprese (PMI). La seconda fase è costituita dall'analisi di un case study al fine di identificare le determinanti che consentono l'adozione della stampa 3D da parte dei clienti business dal punto di vista di una PMI che è fornitrice di tecnologia. I risultati sottolineano che in questo contesto il fornitore di tecnologia deve essere in grado di allineare strategia, rete di filiera e tecnologia sotto l'influenza di alcune forze esterne. Solo questo processo può portare all'adozione dell'innovazione incentrata sul cliente, creando un valore potenziale e reale per i clienti business che non si estingue con il potenziale tecnologico che la stampa 3D già incorpora.

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