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Data lifecycle and technology-based opportunities in new Product Service System offering towards a multidimensional framework

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Abstract

With the advent of the 4th industrial revolution and unprecedented possibility to connect products to the internet, the capability of a firm to collect data and enhance service offering has expanded significantly. An enormous amount of data is generated from connected products and gathered from sensors; data is sent to the cloud via wireless networks and stored, and the possibility to distribute new cloud-based services leveraging data analysis is becoming concrete. Nevertheless, develop such services and create valuable insight both to the final customer and to other users, is not a simple task. Different choices have to be made by the company, which lead to different value and challenges.

With this respect, the paper develops a theoretical framework considering the possibilities a firm can evaluate in the view of data lifecycle. In particular, authors stipulate that the value a firm can offer to the customer changes with respect to the source of data that he/she decided to gather, the storing technology he/she wants to use, and the way he/she wants to deploy the services. The framework can be used as a support to product-based firms which wants to start the servitization path exploiting data availability. The research, at the same time, provides evidence on the evolution of service offerings, which are shifting from a product-centric perspective to a data-centred one and are going to enlarge their scope.

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Keywords: Servitization, Data-Driven services; Cloud-based services; Data analytics, Product Service System

1. Introduction

The trend that sees manufacturers provide services to complement their product offerings it is not recent. Shmenner [1] demonstrate that manufacturing firm began to combine products and services even in the 19th century and from 1988, when the phenomena became notorious in the literature, under the term "Servitization"[2], it has been widely discussed and investigated from different perspectives.

Motivations at the basis of the service-oriented strategy adoption can be different, going from competitive motivations [3] to demand-based motivations [4] or economic ones [5]. Servitization is nowadays omnipresent in manufacturing enterprises [6], which provide, from a customer-centric perspective, a combination of products, services, support and knowledge [3].

Servitization has been evolved over time, and specifically, technology advancement supported the enhancement of product service offerings in different ways. Information and Communication Technologies (ICT) provide advanced infrastructure, enable a smarter way to deliver the service to the customers and create the potentiality to extend the service offering. Internet of Things (IoT) and connected products are at the basis of customer asset virtualization, continuous monitoring and automatic adaptability of the system. Looking at the new frontiers that will arise for what concerns the interdependence between technological advancement and the service offering, data dimension emerges as an imperative path.

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Opresnik at al.,[7] stated that servitization could be thought as a data-intensive process. With new virtualizations of assets, new product-service compositions and, especially, through their usage, the volume of data increases exponentially, and the value a firm can provide to the customer can be enhanced significantly.

Research dealing with data-driven service offering is scant. There are some exploratory studies on the increasing importance of data and the information emerging from it as a source of value in the service context [7][8] but understanding the role of information in enabling servitization is still limited. [9]

In this context, the paper aims to provide additional knowledge to the potentialities that data collection generates in the context of servitization. Indeed, the authors of this research propose a framework aiming to help firms in understanding the implications of different technological choices related to data and suggests that the possibility to integrate data at different extent (i.e. including not only product-related data) can enhance service value.

The paper is structured as follows: Section 2 provides an overview of the servitization phenomena and its relation to information and digital technologies; Section 3 better defines the purpose of the research and clarify its boundaries; Section 4 describes the framework and explains how it is composed; Section 5 is dedicated to the validation of the framework and Section 6 reports conclusions and limitations of the work.

2. Background

The terms "servitization" and "service transition" denote the phenomena that see manufacturing firms enhancing their products by including additional offers, and moving from product-centric offerings towards the service arena [5] [6]. One of the main reasons firms can offer additional services is related to the know-how they already have to keep those products operational and to manage their performance [9]. Based on this knowledge, servitized manufacturers are gradually offering performance-based or outcomes-based contracts (e.g., customer support agreements, risk and reward sharing). Those offerings represent new business models based on the integration of products and services in a bundle and they are known under the term Product-Service System (PSS) [10].

Motivations leading to this decision from the manufacturer side could be various: competitive provocation [3], economic stimuli [5] and customers demand [4] are the most common. Nevertheless, the evolution toward servitization does not necessary leads to successful results. Indeed, if not supported with the right know-how, it can result in limited payoffs and poor revenues, namely "Service Paradox" [11]. Moreover, customers' expectations are becoming more complex, often based on what a product does for the user and not on the product itself [10][12].

In order to overcome these challenges and successfully implement servitization, companies need to find appropriate strategies and approaches [5]. Adopting digital technologies has been always recognized as a possible successful way. In the light of this, it is not surprising that the provision of services relying on digital technologies is increasing, and represents a fruitful sub-stream of research, known as digital servitization [13][14]. It has been demonstrated that digital servitization may help manufacturing firms to add services to their offerings [14][15], improve service quality and reduce operational costs[16].

Technological enhancement supports firms servitization, indeed, ICT provides the right infrastructure to enable services such as remote diagnostics, automatic software updates but also all the alternative to ownership (i.e. pay per use and pay per results[17]). The advent of IoT enables devices to connect with each other and thanks to the transmission to remote servers, it becomes technologically easier to offer tailored-made functions [9].

Cloud computing supports the process of delivering scalable and expandable software services using internet technologies. [4] Cloud platform can provide an excellent environment for large-scale data analysis processing. In this sense, servitization literature has suggested that a platform approach may allow manufacturers to overcome the service paradox [18][19].

Emerging studies on service platforms provide novel insights into the importance of managing digital components that capture the value of information as a key driver of success in the transition toward advanced services [8] [7].

Indeed, data exploitation is recognised as a new source in the service offerings [7], but research on this emerging trend is still at the beginning, and additional studies are required.

3. Purpose and research boundaries

The purpose of this research is to help product-focused companies to undertake a servitization strategy, considering the value that data can provide in the definition of new services. The perspective is always related to the front end of the offering, i.e. the customer has been taken as the focal point, indeed, one of the pillars of the servitization is the customer-centric approach [20].

Particularly, the focus is devoted to identifying the impacts on service offering of different technologies to manage data in its lifecycle.

As a starting point for the framework development, the definition of the research boundaries has to be explained.

First, the authors considered the central component of the new service offering, which is data. Specifically, not only big data in the narrow sense has been taken into account, i.e. not only the once responding to the 5 "V"s (Volume, Velocity, Variety, Value, and Veracity) [21]. Indeed, authors investigate the aspects related to service-offering possibilities based on the data collection, which include the possibility to use big data but is not limited to it.

Secondly, specific benefit and challenges related to all the technologies that will be mentioned are not included in this work: indeed, the research deals with several different technologies which are able to collect/generate data. These technologies have been already investigated and explained in ad hoc literature, comprehensive of several studies on the evaluation of different factors, e.g. security, service level, efficiency, speed in the response, data governance etc.

Instead, what the researchers want to highlight, are the opportunities related to the adoption of specific – data-related – technology for what concern the value of the service that it is possible to offer.

In light of this, the framework proposed in this paper yearns to support firms along the following dimensions:

- Types of data that should be gathered to offer value added service;
- data storage options for customer data;
- data analysis opportunities;
- types of deployment technology for the data-driven service delivery.

4. Framework development

The framework sets its bases on the data lifecycle, specifically, the model developed form Han et al., [22] has been used as a reference. Two small adaptations have been made, and are reported in **Error! Reference source not found.**: "generation" and "acquisition" phases collapsed in "collection" and a final step, i.e. "deployment", has been introduced considering the need to deploy the service to the customer.

For each of the identified phases, the specific interest of this research is defined, underlying its relationship with the value that can be offered to a customer.

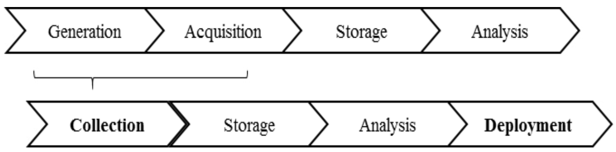

Figure 1 - Data lifecycle (Adapted from [22])

- ***Collection***

Data collection is the first and most critical step to implement. Considering that the technologies to gather data are nowadays mature, the main decision to make is related to the right data to collect. The evaluation is meant to define to which extent they are collected rather than dealing with data types. In particular, the range of data sources can significantly change the service portfolio as well as the competencies that it needs to integrate.

- ***Storage***

Product-service providers need to identify the most suitable way to store customer data. Solutions available on the market offer different possibilities, which can be evaluated in accordance to costs, upload speed, data storage memory etc, but concerning the service the company can offer, the most important factors to be considered are related to privacy, security and trust [23]. Indeed, a firm has to evaluate the possibility that customers do not want to share their data.

- ***Analysis***

Data analysis can be done with different approaches, and the substantial difference, under the authors' interest, is related to the entity who analyses data, that can be based on automatic analysis, predefined methodology, machine learning (ML) algorithms or can include some external persons or companies. Latter options may lead to data sharing concerns from the customer side but introduce the possibilities to gain specific competencies and consequently enhance services.

- ***Deployment***

Regarding the technology that supports the deployment of the service, the main factor to consider is the degree of openness of the support. Give the possibility to other parties to collaborate in the same virtual space to enhance service or provide new services on the same data, brings enormous potentiality to the value of services, since new ideas and expertise are introduced, but concerns from a customer with sensitive data can arise.

The factors identified as critical with respect to the value of the service offering, are also interdependent: they are indeed related to each other, and the combination of different choices may affect the final result.

For each of the defined lifecycle steps, technologies of interest have been defined. The inclusion of some technologies with respect to others is explained in detail and is related to the research scope, which specifically considers the value of service offering that a firm can provide. Figure 2 graphically

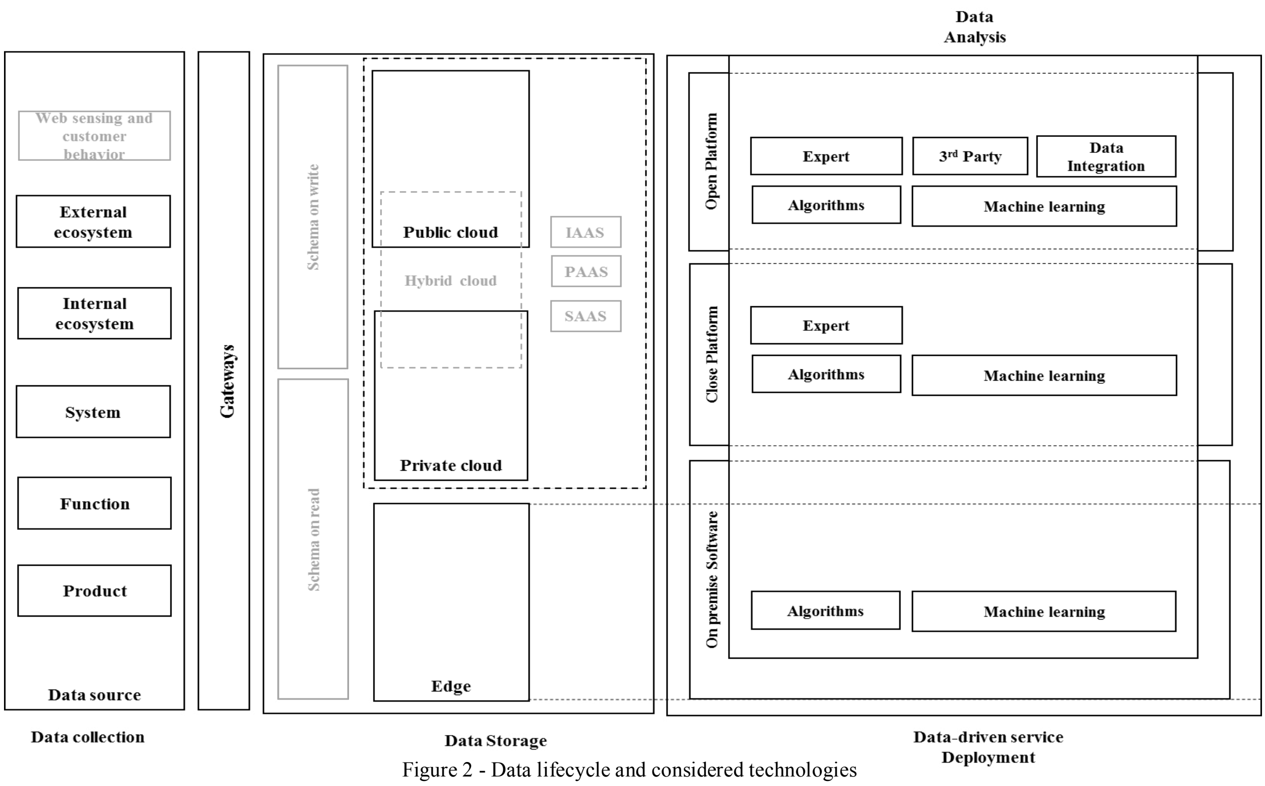

Figure 2 - Data lifecycle and considered technologies

summaries technologies included, that are reported in black. The ones in grey have been recognized relevant in the technological sense, but not critical for this research.

4.1. Data collection layer

Five relevant possibilities have been identified, starting from data related only to the product to the one gathered from the external ecosystem, which can also be combined together. All data typology and their impact are explained in Table 1.

Table 1 - Data collection layer

Data source	Description	Impact on the service offering
Product	Data are related only to the product identity, such as serial number, location, provenience, technical features, age.	The larger is the radius of the data that the firm gathers, the larger is the potentiality of the service. Indeed, the firm can expand its service portfolio and offer to the customer something that is not related only to the product itself but that covers entire solutions.
Function	Data are relative to the main function the product can perform, comprehensive of the history tracing.	
System	Data regarding the system in which the product is primarily included or embedded product functionality.	
Service consumer Ecosystem	Data gathered thanks to the integration of additional sensors or sources within the customer ecosystem, which is the environment in which the product works, such as production scheduling, orders status, etc.	Increasing the information gathered means also that the firm needs to develop knowledge or find the right partnerships to compensate for the competencies that are not in its business.
External Ecosystem	Data are retrieved from a different source of knowledge, which can be related to the external environment.	
Customer behaviour and sentiment*	Data are related to the customer behaviour with respect to the product itself but also to their habits, as well as their personal opinion on the product and more in general on the company.	

The last entry “Customer behaviour and sentiment” has been mentioned for completeness, but it has been excluded from the framework, since data can be used in the back-end analysis to enhance service or to develop new ones, while this research is focused on the value that can be created using data on the customer side, thus the front end.

4.2. Data storage layer

In this layer three are the different possibilities that a firm may choose that can affect the value of the offer at the customer side: *Edge computing, Private Cloud, Open Cloud.*

All the technologies and their impact are explained in Table 2.

Hybrid cloud has been excluded from the analysis since it combines private and public cloud, which means the impact of service offering are treated separately in the other two cases.

Table 2 - Data storage layer

Data storage technology	Description	Impact on the service offering
Edge computing	Computing applications, data, and services are pushed to the logical extremes of a network This approach requires leveraging resources that may not be continuously connected to a network such as laptops, smartphones, tablets and sensors.	Edge computing enables data gathering and analytics to occur at the source of the data, offering the possibility to do not share data with other parties. Cloud computing systems include compute, storage, and analytic power to consume in servers that do not belong to the customer, which can strongly influence the willingness to share data from the customer side.
Private cloud	Data and processes are managed within the organization either on a server into the company itself or on an individually assigned server in the highly secure data centre of an external service provider.	
Public cloud	Resources are dynamically provisioned on a fine-grained, self-service basis over the Internet, via web applications/web services, from an off-site third-party provider who shares resources with many customers.	
Hybrid cloud*	The environment is consisting of multiple internal and/or external providers.	

Apart from the Edge computing, all the different cloud solutions are nowadays available on the market in different architecture, enabling users to use specific technologies only when needed, and often dispose of them after the job is done. Those architectures are *Infrastructure As a Service (IAAS), Platform as a Service (PAAS) and Software as a Service (SAAS)*. [24] Different cloud architectures can lead to specific gains to the user in terms of cost efficiency, rapidity of response etc., [25]. In this specific context, they have not been recognized as critical, indeed the value of the service offered to the customer wants to be analysed beyond technicality and considering the possibilities to rely on the best technology available.

Another point that needs to be considered in system architecture is the way the database is written. Figure 2 reported two different methods, i.e. *schema on write; schema on read,* which respectively means that a schema is defined for data before writing into the database and that the schema is created only when reading the data, enabling more flexibility for unstructured data storage. Even this point is considered to go beyond research boundaries since it is related to the data typology and technical choices.

4.3. Data analysis layer

A substantial difference in the value of service offering can be recognised in the entity who perform the analysis. In accordance with this, three different groups have been defined: *Algorithms and ML; Experts,* and *3rd party*. Those categories and their impact are explained in Table 3.

Table 3 - Data analysis layer

Data analysis technology	Description	Impact on the service offering
Algorithms and ML	Analysis is entrusted to specific predefined algorithms	The type of data analysis is directly linked with the value of the service offered since the higher are the competencies on the data and its domain; the greatest is the potential to offer innovative and suitable solutions.
Experts	Persons who own the right competencies both in terms of data management and on the field of analysis are enrolled in the analysis to provide additional insight.	
3rd party	Data can be exploited from different companies, which own different competencies and could create a completely different and complementary service offering with the right know-how.	

4.4. Data deployment layer

For what concern the deployment of the service, three main options emerge, which can significantly affect the final result: *on-premise software, close platform,* and *open platform*. Descriptions and impacts are explained in Table 4.

Table 4 - Data Deployment layer

Data deployment technology	Description	Impact on the service offering
On-premise software	On-premises software is installed and runs on computers on the premises of the person or organization using the software, rather than at a remote facility.	If data are not shared with some others, the customer will not have issues regarding the data privacy and trust, nevertheless, data cannot be analysed by external experts and it limits the extent of the offer.
Closed Platform	Software system where the carrier or service provider has control over applications, content, and media, and restricts convenient access to non-approved applications or content.	If data are shared, through cloud-based data storage systems, analysis can be done at the service provider side but there is not the possibility to make data analysed from other companies if not allowed and employed form the company.
Open platform	Software system based on open standards, supporting application programming interfaces (API) that allow using the software to function in other ways than the original intent, without requiring modification of the source code.	In an open platform environment, third parties could operate on the platform to add functionality and enlarge the possibilities to customize solutions.

4.5. The proposed framework

Considering data lifecycle phases, critical technologies and the impact on the value of service offering, the final framework has been defined and reported in Figure 3.

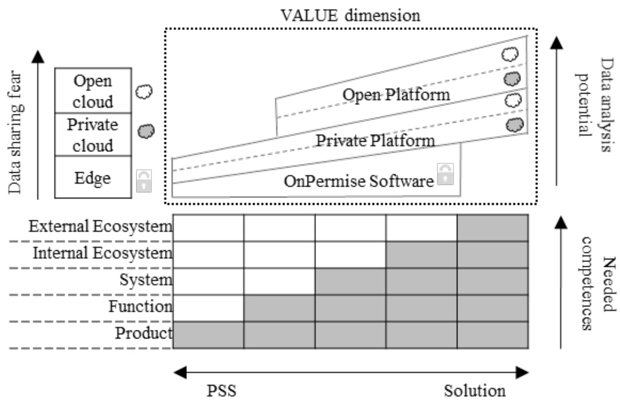

Figure 3 – Data-Technologies-Value of service (framework)

Figure 3 represents a summary of the previously explained factors and their inter-relation. It includes the prementioned layers and introduces the "value" dimension, which denotes how the combination of different solutions belonging to data layers, impact the service offerings. As it is possible to notice, the "value" increases with the data extent, and also with the openness of the service infrastructure. Nevertheless, two exception emerges: first, the value an on-premise software can offer is limited compared to the other deployment technologies since it is quite limited in its scope and adding external ecosystem data can be limited. Additionally, data remain at the customer side and the firm cannot leverage other expertise. Second, with respect to product and, in part, function data, open platform creates a poor additional advantage. Indeed, the firm owns the know-how on the products functioning and the collaboration with other companies will lead to limited enhancement compared to the ones reachable with the other data source.

5. Framework verification

The framework has been evaluated and verified with two successful, already commercialized, cases. They have been selected with respect to the service offerings, and the availability of public information of those offers. The mandatory requirement during the case selection was that services are enabled by the data the companies collected and that are offered, at least some of them, on cloud platforms. Case studies were also chosen considering different fields of application, in order to demonstrate the applicability of the framework at a large spectrum.

Company Alpha

The company is an American corporation that produces agricultural, construction, and forestry machinery, diesel engines, drivetrains used in heavy equipment, and lawn care equipment. The company had always recognized the importance of providing additional services to customers, and specifically, the case study we considered is related to the farming field.

The company started to equip its product with different sensors in order to gather data and to offer solutions based on those data. Moreover, it also offers the possibilities to send the data to a company owned Operation Center, where data can be analysed from experts and also integrated with other data sources. The company relies on more than 30 partner companies to offer highly customized and specific additional services.

The result is the offering of complete solutions that go beyond the mere essential services on the product and reach the complete system in which the product is included.

Table 5 - Framework applied to company alpha

	Product	Function	System	Internal Ecosystem	External Ecosystem
Source	Tractor	Working	Object inside the tractor	Field to grow	Environment
Example of data	Machine location, ID	Health conditions, hour usage	Average moisture, seeding variety and rates	Soil temperature, cultivation, quality, extension of the yield	Air temperature, solar radiation levels, precipitation
Service offering on top of the product	Fleet management	Condition-based alerts Remote diagnosis	Seed mix adjustment	Field fertilization Operation optimization Field utilization Automatic guidance	Nutrient analysis Reduce feed variability

Company Beta

The company is one of the largest manufacturers of heavy-duty truck worldwide. Its core activity is the production, distribution and sale of trucks, buses and construction equipment. The multinational company is also working on proactive services and recognized the great potential of product connectivity and data analytics to offer advanced solutions and extend its service portfolio.

The company approaches service offering in an openness perspective: thought the developer portal they welcome and enable new, innovative services to be developed by selected specialist partners and others. The result is that the company can offer services not only related to the truck itself but to the complete fleet management and operation optimization.

Table 6 - Framework applied to company beta

	Product	Function	System	Internal Ecosystem	External Ecosystem
Source	Vehicle	Move, transfer	Vehicle, drivers	Roads and infrastructure, planning	Environment
Example of data	Vehicle position	Health conditions of parts Truck movements	Fuel consumptio n, Speed, Drivers Behaviour	Charging stations, final destinations	Traffic conditions, Environment Reports
Service offering on top of the product	Alerts	Trouble codes and monitor the status of crucial components	Performance monitoring	Fleet efficiency optimization	Road optimization
	Vehicle asset management	Predictive maintenance	Driver time forecast	Managing driving	Environment al impact estimations
		Monitoring		Manage vehicle availability	

6. Conclusion and research limitations

Firm's journey to digital service innovation is not an easy path, and the proposed framework aims at supporting a critical technological and strategical decision, using the available tools to offer new services and considering the value that it is possible to bring to the customer as a primary metric. The framework is based on data lifecycle and includes the extent of the data that a firm can gather the way the data is stored, analysed and deployed.

The research provides a summary of the available technologies and on the impacts that they can have on the final offer. In particular, the larger is the extent of data gathered, the higher are the possibilities to enlarge the service portfolio and to offer large-scale solutions, rather than single services. Manufacturing firms were used to offer advanced services on top of the product, relying on their core to keep those products operational and to manage performance [9]. Nevertheless, leverage data analytics to explore new service offering can lead manufacturers to provide product and service combinations that play a key role in customers' core operations, and not only on the product itself, going to satisfy customer demand [12]. Secondly, the higher the possibility to include new competencies in the data analysis, the more significant the options to create valuable services and create complete solutions. In this context, the firm has to consider customer willingness to share its data and the possibility to enable 3rd parties to leverage its technologies and data to collaborate in the value creation.

The research qualitatively indicates that the value the firm can offer increases under certain conditions; nevertheless, one main limitation is that this evaluation is dependable on each different case, since different data exploitation strategy can lead to different results, and each customer has its own preferences. What is it possible to state, at least for the degree of analysis of this research, is a scale of value, as reported in Figure 3. Additionally, the research does not consider the resources that a company need to invest in this transformation and does not evaluate the monetary benefit that it can reach. Profitability analysis can be performed to evaluate the real benefit of adopting data-driven servitization strategy to overcome the service-paradox. With this regard, it has been shown that rely on external partners to also leverage their resources and expertise, enable firms to do not allocate too much effort for new services. However, new dynamics are also emerging in the creation of this Manufacturing service Ecosystem (MSE) [20], thus, understand how the ecosystem is evolving can also be deeply investigated.

As already stated, understanding information compared to products and services in enabling servitization is at its beginning [9] and the paper provides an initial contribution to this promising phenomena. Moreover, the highly complex context, which involves several and different research areas that overlaps to each other, and that could influence several business dynamics, creates the perfect background and many opportunities to conduct more in-depth investigations.

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