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Product-Service Systems across Life Cycle

Exploring the key enabling role of digital technologies for PSS offerings

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Abstract

The adoption of digital technologies has been identified as crucial for manufacturers moving to service-based business [18,27,28]. However, it is not clear how technological improvement are central to develop key capabilities for business and service innovation [1]. This paper aims at filling this gap, focusing on the following aspects: 1) the key capabilities enabled by digital technologies to support servitization transformation; 2) the relationship between each specific value proposition and those capabilities. To ground our findings on extant research, we adopt the classification provided by [19], and we refer to three strategies, namely equipment suppliers, availability providers and performance providers.

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Keywords: PSS; Service-oriented Strategy; Product-Service offering; Digital Technologies; Information management capabilities

1. Introduction

Scholars agree that the adoption of digital technologies is crucial for manufacturers to move to service-based business [18,27,28]. For instance, [33] affirm that a contribution to service success requires investments in information and communication technologies. In addition, [41] state that installed bases are the most valuable asset for manufacturers, that should leverage ICTs to collect, analyze and interpret field data. However, most contributions tell few words about how digital technologies can favour the shift to a service-based business, exceptions being [2,3,5,17,21,32]. In particular, the extant research neglect how the advent of disruptive technologies - such as cloud computing or internet of things - can influence this journey. In this paper we speculate that the role of digital technologies strictly depends on the type of product-service offerings [26,35,38], as well as on the strategy adopted to servitize [19,30]. In this vein, the paper addresses the following questions: 1) which capabilities – among those enabled by digital technologies - are relevant for the shift to service-based business of product-centric companies? 2) which are the linkages among these capabilities and the different strategic profiles of servitization? Hereafter, the term capability takes the meaning of the "firm's capacity to deploy resources for a desired end result" [15]

The rest of the paper is organised as follows: Section 2 introduces the literature review. Section 3 is focused on building and explaining the framework, while Section 4 draws conclusions and points out limitations and avenues of future research.

2. Literature review

To achieve a thorough understanding of the topics of our interest, in the next sub sections we give an overview of the relevant findings on: 1) digital technologies that enable servitization and 2) strategic profiles of servitization.

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2.1. Digital technologies for servitization

Digital technologies are radically changing the way services can be delivered [6] and scholars agrees that it is hard to deal with service innovation without considering technology [29]. Simply put, ICTs are integral to a growing number of services [7] so that it is said that "the service revolution and the information revolution are two sides of the same coin [37]. In their shift to a service business, manufacturers introduce digital technologies to increase the efficiency of service delivery [16] and logistics support [8], to raise the value of their offerings as a direct consequence of technology-enabled integration of product and services [13], and to differentiate the company's offering [5,18]. In addition, cloud computing and smartphones applications enable always-on anytime/everywhere channels, through which customers can demand for and receive digital services [11].

Another stream of research focuses on those technologies that introduce awareness and connectivity on products, to enable the provision of advanced services [21]. As far as the age of the Internet of Things raises, connected products spread everywhere [11,23]. By connecting products to their remote centres, manufacturers can provide services such as predictive maintenance and remote control in a smarter way [2]. As far as billions of field data are collected, on the one hand manufacturers are expected to gain manifold insights about new business opportunities [32], on the other hand firms can make a big deal of money exploiting these data [10,36].

Although previous studies show consensus on the relevance of digital technologies in the journey to service business, a comprehensive view is still missing. In particular, it is not clear how technological improvement are central to develop key capabilities for business and service innovation [1]. To overcome this gap, this study identify which capabilities are introduced by the following innovations, that we considered to be relevant for our aims: 1) Internet of Things (hereafter IoT) and industrial internet; 2) cloud computing; 3) predictive analytics. In this paper, IoT identifies those capabilities that, recurring to sensors and microcomputers, enable manufacturers to collect data from installed bases [41]. Cloud computing includes a bunch of technologies, services and applications that allow to seamlessly store, combine and share, over the internet, big amount of data in a very cost effective way. Predictive analytics includes technologies that support analysis of data, in order to diagnose and predict behaviour, respond, adapt - even autonomously [32] and/or determine appropriate intervention [21]. Figure 1 depicts the structure of technological innovations considered in this paper.

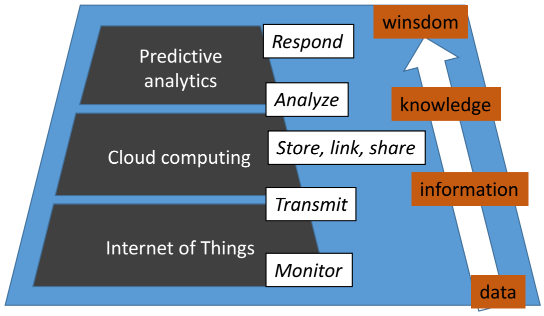

Figure 1: Structure of technological innovations considered in this study

In the following, we do not consider other kinds of technologies that, as pointed out in the review, mostly focus on enhancing the service delivery process.

2.2. PSS strategic profiles

In the last 25 years of research, many scholars have explored the importance of implementing integrated product-service offerings, considering them as a powerful source of competitive advantage [20]. Different models, adopting complementary perspectives and combinations of descriptive characteristics, have been proposed to illustrate how the change of product-service offering translates into differing levels of service sophistication [21, 28, 38, 21, 40]. The majority of existing studies have adopted the lens of a traditional good-base thinking with Business to Business perspective and describing service transitioning along with three main dimensions:

1. From product to process-oriented services [3,9,28,34,41,42]
2. From standardized to customized services [25,31]
3. From transactional to relational services [28,31]

To overcome the traditional goods-centric view that, implying the sole provider responsibility for 'service activities' delivery may impede the understanding on how customers realise value, a service value-centred viewpoint has been recently taken into account. For instance, the model introduced by [21] distinguished service transformation along with three types of propositions, differing on the base of who is responsible for deciding when and why services should be provided. In addition, [38] proposed a value proposition cycles model that provides three distinct propositions of value with three multiple, simultaneous and iterative primary transformation paths: the recovery value is offered by minimising disruption, the availability value is proposed by maximising potential use while the outcome value presented by supporting capability to better achieve desired outcomes. Moreover, since service systems are considered to be open, integrating discussion on servitization transformation with a relationships and network perspective emerged as essential [14].

Nonetheless, research on organisational change towards a service-oriented strategy still appears to be lagging behind. Indeed, the majority of existing studies states that companies moving along a servitization continuum undertake a linear and unidirectional repositioning of their PSSs [40]. However, as argued by [19] the established assumption underlying the service transition is problematic, since "servitization is more multifaceted and multidirectional than literature assumes". In other words neglecting the product-service dichotomy, according to which product are seen as standardized while service as customized, companies do not purse one specific service strategy, but they combine different strategies and offerings, undertaking multiple positions along the continuum at the same time. Moreover, while transitioning toward more advanced process-oriented strategies "firms expand their business through the addition of new, and the building of existing services to their portfolio, infusing higher levels of service into their offerings." This implies the integration of structural and infrastructural capabilities and requires the coexistence of traditional and innovative strategic and operational patterns.

On these premises, the three main service growth trajectories proposed by the authors (becoming availability provider, becoming performance provider and becoming industrializer) clearly depict a transformation towards a more service-oriented strategy and adopting a multi-perspective view, able to capture at the same time B2B and B2C peculiarities, due to the comparability of the model to general categorisations referring to both settings [40]. In particular, when a manufacturer moves from equipment to availability provider it starts bundling core products with additional services. The offering expands from basic to more advanced services and the existing capabilities are exploited to increase customer loyalty and business growth. Becoming a performance provider requires manufacturers to start offering more advanced solutions to solve long-term strategic customers' needs. Customer and supplier share development capabilities and services are mainly relational, customized and output-based. Finally, when a company becomes an industrializer, it might decide to standardize, or "productize" customized service solutions, to create the prerequisites for scalability and repeatability, to reach a larger customer base. Customers, indeed, highly rely on the provider's expertise and development capabilities, paying only for the achieved results and value-in-use.

3. A conceptual framework to link digital technologies and strategic profiles

This section builds on the literature review carried out in the previous sections and the conceptual elaboration of the authors in order to develop the conceptual framework of this research. Our aim is to provide details on the information management needs and investigate how digital technologies enable such capabilities in relation to the strategic profiles adopted in firms with service-oriented strategy [19].

The relationships among the technologies, the strategic profile and the capabilities are depicted in the conceptual framework in Figure 2.

Eleven information management capabilities are analysed in this paper.

- **Identification (user)**: Identification of the specific user of a product in each specific usage instance;
- **Identification (product)**: Identification of the specific product (e.g. serial number) and its specific Bill-of-Materials and components/materials ID;
- **Geo-localisation**: Association of a specific location to each product and usage or time instance. It makes a difference whether the product is moving (e.g. car, forklift truck) or static (e.g. large equipment);
- **Timing assessment**: Association of a certified timing (end, finish, duration) to each usage instance.
- **Intensity assessment**: Measure of the amount of usage of the product (e.g. how much time, km). It is related to the measurement unit used to determine the intensity of amount of usage of a product, that can be either an usage condition (e.g. hours of work of a ball bearing) or directly related to an output (printed pages, units processed);
- **Condition monitoring**: Continuous monitoring of the state of relevant product parameters (e.g. pressure, temperature, speed);
- **Usage monitoring**: Association of each usage instance to a specific mission or task;
- **Prediction**: Analysis and interpretation of condition (and usage) patterns, in order to predict the future condition of critical parameters and thus of the specific product or part;
- **Adaptive (remote) control**: It allows acting directly on the product parameters based on the Condition Monitoring and/or Prediction capabilities described above;
- **Optimization**: The usage of the information collected and analyzed (both real-time or on historical data) to improve product efficiency (e.g. energy or fuel consumption) or utilization, or performance;
- **Autonomy**: Autonomous management of certain functions and connections with other product and systems performed by the product itself.

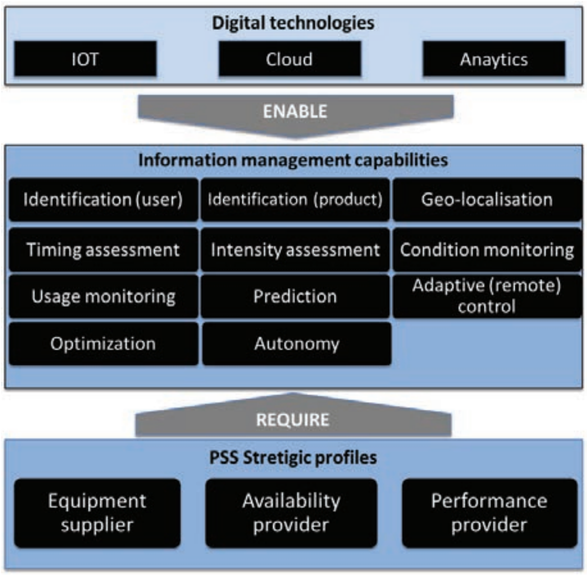

Figure 2: Conceptual framework

In order to make the list more understandable for the reader, Table 1 depicts the related objective for each of the above-mentioned capabilities trying to state a related question.

Table 1: Related questions to the information management capabilities

Capability	Question related to the capability
Identification (user)	Who is using the product in a specific time instance and/or usage instance?
Identification (product)	Which specific product instance and product configuration is under consideration?
Geo-localisation	Where is the product located (in a specific time / usage instance)?
Timing assessment	When / for how long the product has been used (in a specific usage instance)? At what time a specific condition datum has been collected?
Intensity assessment	How much that product (or a specific part) has been used (overall or in a specific usage instance)?
Condition monitoring	How is the product (or a specific part) working? What are its working conditions?
Usage monitoring	Why or What for is the product (or a specific part) used?
Prediction	What then? What a specific product (or part, or parameter) condition will lead to?
Adaptive (remote) control	How can the issue be solved or the user experience improved?
Optimization	How things can be done better?
Autonomy	"How can the product do it by itself

Table 2 graphically summarizes the relative importance of the three families of technologies in enabling the different capabilities. Since IoT concerns different devices such as sensors and actuators, it is important for almost all the capabilities identified in this paper. However, we think that the role of IoT is crucial for adaptive (remote) control and autonomy. On the one hand IoT performs important functions both passively (receiving data from the product) and actively (sending data to actuators in order to perform action to the product) to preform adaptive (remote) control; on the other hand, for autonomy capability, IoT is crucial because it allows the relationship and connection among the several products which characterize the system (or the installed base). The role of IoT in prediction and optimization is instead marginal, while it is very important the function performed by predictive analytics. The role of cloud technology is essential when the amount of data to be stored from the installed base. In our opinion the intensity assessment, condition monitoring and usage monitoring are capabilities related to activities that require the storage of big amount of data. Cloud is also important for storing information about the identity of users and product, but the importance depends in particular on the number of users and the broadness of the installed base.

Table 2: The enabling role of the three technological families for the information management capabilities (++ = very important; + = important)

Capability	IOT	Cloud	Predictive Analytics
Identification (user)	+	+	
Identification (product)	+	+	
Geo-localisation	+		
Timing assessment	+		
Intensity assessment	+	++	
Condition monitoring	+	++	
Usage monitoring	+	++	
Prediction			++
Adaptive (remote) control	++		+
Optimization			++
Autonomy	++		+

The second part of this section deals with the description of the role and importance of these capabilities in the three PSS offering profiles described in the previous section, namely: Equipment supplier, Availability Provider, Performance provider. Table 3 provides the impacts of the capabilities identified in this paper for each PSS strategic profiles described in the previous section.

Table 3: Impacts of information management capabilities in different PSS profiles

Capability	PSS Strategic profiles requirements
Identification (user)	**Equipment supplier**: Not particularly relevant
	Availability provider: Useful for pay-per-use or access-based contractual scheme. Also important for fleet management issues to identify the responsible of the actions on the product.
	Performance provider: It is an enabler of more advance capabilities (personalized analytics, optimization, …)
Identification (product)	**Equipment supplier**: Enables a correct warranty management activity (it allows retrieving the warranty status of the product/part).
	Availability provider: Same as "equipment supplier" and important particularly fleet management contracts, allowing to identify the specific product/part instance. Also important for pay-per-use or access-based contractual schemes.
	Performance provider: Same as "availability provider" with the potentiality to enable the correct measure of actual performance against performance targets or agreed SLAs on single products
Geo-localisation	**Equipment supplier**: May enable a correct warranty management activity (for no-moving products)
	Availability provider: Important for moving products, in particular for granting access to the product (e.g. carsharing services) and for a correct maintenance contract management activity
	Performance provider: May be useful for the identification of responsibilities for misuse (depending on the kind of product)
Timing assessment	**Equipment supplier**: Static information needed to trace purchase and end of warranty date, for warranty management activity
	Availability provider: It is/may be required for activating a transaction and for pricing / billing purposes and correct maintenance contract management activity
	Performance provider: Relevant to associate

	other information to a moment in time, to enable real time monitoring and/or historical data analysis
Intensity assessment	**Equipment supplier**: Not particularly relevant **Availability provider**: Measuring the intensity of product usage in a specific instance (e.g. distance covered by a car; printed pages by a printer, minutes of call or data downloaded with a smartphone), … **Performance provider**: Same as Availability provider. Moreover, it allows measuring actual performance of the product/component and comparing it to targets (e.g. target vs. actual MTTF; target vs actual production rate).
Condition monitoring	**Equipment supplier**: Not particularly relevant **Availability provider**: Important for pay-x-use contracts in order to maximize revenues for the manufacturer (the more the product is working, the more the product is used) **Performance provider**: It is fundamental to monitoring parameters when they are related to the achievement of the result promised in the PSS offerings (target performance)
Usage monitoring	**Equipment supplier**: Not particularly relevant **Availability provider**: It may be useful to understand the causes of problem in case of a fleet management contract **Performance provider**: It supports the identification of the best (customized) solution to achieve customer objectives. It supports also the development of new standard services to support customers achieving their specific objectives
Prediction	**Equipment supplier**: Not particularly relevant **Availability provider**: It is important for particular contracts related to fleet management and predictive maintenance **Performance provider**: It is strategic for the manufacturer to predict likely problems on the product in order to respect the terms of contract (e.g. to respect SLA)
Adaptive (remote) control	**Equipment supplier**: Not particularly relevant **Availability provider**: It enables maintenance contract management **Performance provider**: Embedding or enabling real time intervention on the product in case of issues support the achievement of the agreed performance levels
Optimization	**Equipment supplier**: Not particularly relevant **Availability provider**: Not particularly relevant **Performance provider**: It supports the achievement of the performance targets
Autonomy	**Equipment supplier**: Not particularly relevant **Availability provider**: Not particularly relevant **Performance provider**: Depending on the kind of product, autonomy may be an important capabilities to respect terms of contracts and guarantee the performance

Considering the impacts of the different capabilities on the three PSS strategic profiles described in the paper, Table 4 tries to summarize the importance degree of each capability for the identified strategic profiles.

Table 4: Intensity of the relevance of different Information Management Capabilities in different PSS strategic profiles (++ = very important; + = important; (+) = important based on the industry)

Capability	**Equipment supplier**	**Availability supplier**	**Performance supplier**
Identification (user)		++	+
Identification (product)	+	++	++
Geo-localisation	(+)	+	(+)
Timing assessment	(+)	++	+
Intensity assessment		++	+
Condition monitoring		(+)	++
Usage monitoring			+
Prediction		(+)	++
Adaptive (remote) control		(+)	++
Optimization		+	++
Autonomy		(+)	(+)

4. Conclusions

In recent years several companies are moving towards a more service-oriented strategy, through the adoption of different strategic profiles, in order to face the increasing global competition [4,40]. The adoption of digital technologies is a key enabler for the provision of many services related to an integrated product-service offering [2,3,5,17,21,32] . Despite several scholars have argued about digital technologies in the development of an integrated product-service strategy, the impacts of each technology is under-investigated in literature [1]. This paper has identified 11 key capabilities (identification of user, identification of product, geo-localization, timing assessment, intensity assessment, condition monitoring, usage monitoring, prediction, adaptive control, optimization and autonomy) enabled by three digital technologies (IoT, Cloud and predictive analytics) that are required to move towards one of the three PSS strategic profiles identified by [19], namely equipment supplier, availability supplier and performance supplier.

In previous section, based on a literature review carried out on the topics of digital technologies and PSS strategies, we have: 1) described the impacts and the importance of each digital technology in the enablement of eleven key capabilities; 2) the likely effect of each capability for the development of particular strategic profiles. As with any research, our study is not without limitations as the framework developed, in particular the relationships between the technologies and the strategic profiles, has not been validated by the application on real business cases. For this reason, considering future research trends, we are going to apply the presented framework on three particular business case studies in order to refine and validate both the capabilities identified and their relationships with the digital technologies and the different strategic profiles.

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