

Smart manufacturing as an enabler of servitization: a framework for the business transformation towards a smart service ecosystem

Cimini C.*, Rondini A.*, Pezzotta G.*, Pinto R. *

* *Department of Management, Information and Industrial Engineering, University of Bergamo, via G. Marconi 5, 24044, Dalmine (BG) – Italy (chiara.cimini@unibg.it, alice.rondini@unibg.it, giuditta.pezzotta@unibg.it, roberto.pinto@unibg.it)*

Abstract: In recent years, many companies have been forced to move their businesses from a product-centric perspective to a product-service integrated offering. This strategic transformation has been called “servitization” and represents one of the major opportunities for companies that wish to add value to their traditional product-based offerings, differentiating from competitors and generating additional revenues. Moreover, the introduction of new digital technologies is pushing the transformation of traditional manufacturing into smart manufacturing, in order to enhance the productivity and the efficiency of the production exploiting IT technologies. Starting from the German initiative called “Industry 4.0”, many researchers and practitioners are trying to describe the transformation path towards smart manufacturing. In this paper, the digital transformation of enterprises is considered as an enabler of the servitization process. In particular, a set of technologies and methodologies of Industry 4.0 are associated to the challenges that companies have to face, moving their business from a product-oriented to a service-based value proposition. The aim of the paper is to jointly analyze the servitization and Industry 4.0 transformation processes and to formalize a combined transformation path that can enhance companies’ competitiveness. Starting from the analysis of academic and industrial literature, a framework describing the servitization and smart manufacturing transition is presented to depict the steps required to build a digital servitized ecosystem. The work contributes to both theory and practice to the fields of servitization and Industry 4.0. Managerial implications and limitations of the presented framework are discussed and further developments of the research are proposed.

Keywords: Servitization, Digitalization, Product Service System, Business transformation, Industry 4.0

1. Introduction

In recent years, many companies shifted their businesses from a product-centric perspective to a product-service integrated offering. This strategic transformation toward the provision of services is called “servitization” and represents a major opportunity for companies that can differentiate from competitors and generate additional revenues adding services to their traditional product-based offerings (Vandermerwe and Rada, 1988). Servitization in manufacturing consists of the combination of product with associated services, support and knowledge (Baines et al., 2009) in a customer-centric perspective. In the context of servitization, the fulfilment of customer needs represents the key value to succeed. In the light of this, services are not just considered as a mere add-on to a physical product: instead, they are bundled with the product to deliver “a market proposition that extends the traditional functionality of a product by incorporating additional services” (Baines et al., 2007). This mix is also referred to as Product-Service System (PSS). Nowadays, many companies are proposing a wide offering of PSS in order to be competitive in the market and to generate long-term relationships with customers.

However, the evolution toward the PSS poses several challenges (Zhang and Banerji, 2017) that, if not supported with the right know-how, can result in limited

payoffs and unsuitable revenues, namely “Service Paradox” (Gebauer et al., 2005). Among these challenges, a substantial shift in terms of organizational principles, structures, and processes (Gebauer and Fleisch, 2007) is required together with new management of the relationship with customers and suppliers that, in the new PSS paradigm, are more intense and frequent (Evans et al., 2007). In order to overcome these challenges and navigate successfully toward servitization, companies need to find appropriate strategies and approaches (Oliva and Kallenberg, 2003).

In last years, in parallel to the evolution toward services, traditional manufacturing companies have also been affected by the introduction of new advanced technologies, which spur the change of their production processes into smart manufacturing ones, enhancing their productivity and efficiency. Starting from the German initiative called “Industry 4.0” (Thoben et al., 2017) many researchers and practitioners are trying to describe the transformation path towards smart manufacturing.

In the light of these two transforming forces, this paper aims at contributing to the current body of research proposing a model of a joint business transformation towards smart manufacturing and servitization. In particular, it shows how digitalization and the technologies offered by Industry 4.0 can support the servitization process. Throughout the paper, key enabling technologies

(KETs) associated with the Industry 4.0 domain, also named as smart technologies, will be listed and their possible contribution to face the challenges of servitization will be proposed.

Based on a literature analysis, reported in section 2, the major servitization challenges will be highlighted. In section 3, a brief description of the pillars of Industry 4.0 will be presented in order to associate the advantages of the KETs to the named challenges. In section 4, the focus will be on the proposed model for the joint adoption of servitization and digitalization, highlighting how companies can change their business, getting more efficient and improving their customer relationships. Finally, in section 5, theoretical and practical implications of the presented model will be discussed.

2. Servitization challenges

As hinted in the introduction, the transition toward the provision of PSSs implies a whole change into the companies' organization: indeed, they have to adapt to an entirely new value proposition and understanding of business. This is due to the necessity of PSS provider to manage a high number of partners and to establish a long-term relationship with customers (Mont, 2002). The risk associated to the new solution, the necessity of high commitment and leadership, and the need to manage a new and different timescale (Ardolino et al., 2017)(Martinez et al., 2010)(Alghisi and Saccani, 2015)(Zhang and Banerji, 2017) are just some of the challenges to be faced through servitization. In general, as highlighted by (Ardolino et al., 2017) the complexity of the servitization transition is composed of three main components:

1. From products to process-oriented services
2. From standardized to customized solutions
3. From transactional to long-term agreements.

First of all, the provision of services in addition to products requires the development of new capabilities and processes associated with the product (Martinez et al., 2010). The product is not merely sold to the customer: it should be supported and, in some cases, monitored throughout the entire lifecycle to ensure its right functioning. Instead of just selling the product “one-shot”, companies have to take care of it through the lifecycle, optimizing its efficiency and improving its functionalities with multiple services.

More than this, it is worth mentioning that services, by definition, are usually more customized than pure products (Matthyssens and Vandenbempt, 2008). Hence, the variety and the number of products that could be sold would increase exponentially. This is further exacerbated considering the possible combination of products and customized services, as well as the way in which they can be provided to the customer. In relation to this, companies have to increase their capabilities in managing products and service variants, being agile and being ready to develop “ad-hoc solutions for customers through the so-called “co-design” process” (Alghisi and Saccani,

2015). The development of suitable knowledge management approach reveals essential for the management of all the variants.

Finally, the third major area of change implies the management of the relationship with customers. As hinted with respect to the transition from product to service process, the introduction of PSS requires the development of relational capabilities to manage customers' relationships that enable the organisation to compete in new service spaces. *“An integrated offering implies a greater number of customer touch-points, with the result that a broader range of personnel is being exposed to the customer than previously”* (Martinez et al., 2010). Hence, the number of staff members who interact with the customer increases. To do so, it is very relevant that all the personnel involved remain consistent with one another.

These three main categories of challenges constitute the most significant shift that companies have to face while moving toward servitization. Although many companies succeed in manage this shift, they still remain quite critical for a number of other businesses. To cope with this, the next section of the paper deal with these challenges and the smart technologies that could potentially help in face them.

3. How Industry 4.0 can support Servitization

According to (Mittal et al., 2017), within the phenomenon of Industry 4.0, it is possible to recognize several characteristics, technologies and enabling factors. Kang et al. (2016) identify eight key technologies of Smart Manufacturing, while in (Hermann et al., 2015) six design principles for Industry 4.0 are described.

In the literature, Rübmann et al. (2015) give an exhaustive overview of a mix of nine technologies/characteristics that are pillars for the business transformation of manufacturing towards smart production. As already hinted, this paper argues that these pillars could support companies in overcoming the servitization challenges. Table 1 reports the list of these nine pillars linked to the three major components of servitization complexity as a mean to design the relationships between them.

First, it is remarkable that smart sensors and Industrial Internet of Things can have a great impact on the traceability and monitoring of product and processes. The lifecycle management of the products and services could be then enhanced allowing the suppliers to be aware of the actual functioning of their products when they are integrated into the final production environment (Shmidt al., 2015). In addition, cloud technologies offer the availability of real-time data collected from products and processes, remotely accessible by different stakeholders along the value chain (from design to utilization), allowing the data processing and analytics (Park, 2013). The above-described technologies and scenario could then enhance the capabilities of companies in moving toward a process-oriented mind-set, enhancing a full horizontal integration inside and outside the factory, promoting higher performance in product-service delivering (e.g. logistics).

Regarding the challenges associated with the management of customized solutions, cloud platforms and data sharing are crucial for supporting co-design and the increasing demand for customized product-service solutions as well. In fact, virtual environment can be used to enhance collaborative design practices between customers and suppliers to co-design customized solutions (Schuh et al., 2014). To overcome the challenge of customization, a “hardware” technology, such as additive manufacturing could also bring important potentialities. In particular, additive manufacturing supports the production of highly customized products in single batches with low resource waste in terms of material and energy (Kang et al., 2016). This could support quick and easy prototyping of the proposed solutions that could favour the PSS customization. In addition, to ease the production of customized products, it could be useful to adopt advanced robots, which are able to interact and learn directly from humans (Thoben et al., 2017).

Table 1: I 4.0 Technologies vs. servitization challenges

	From products to process-oriented services	From standardized to customized solutions	From transactional to long-term agreements
Big data and analytics	✓		✓
Autonomous robots		✓	
Simulation	✓		
Horizontal and vertical integration	✓	✓	✓
Industrial Internet of Things (IIoT)	✓		
Cybersecurity	✓		✓
The cloud	✓	✓	✓
Additive manufacturing		✓	
Augmented reality			✓

Finally, horizontal integration and in-the-cloud data analytics favour the transition from a transactional to a relational approach to customers, since the interactions among stakeholders are eased. The suppliers can gain advantages in analysing the performance of the delivered product-service solutions, improving their offering based on the customers’ use and providing additional services (Thoben et al., 2017). Also, tools for augmented reality can support traditional services that are product-related and involve the relationship between customers and suppliers, such as training.

In this collaborating eco-system, one of the major challenges is to ensure a safe data exchange (Khan and Turowski, 2016), to protect the intellectual property from hackers’ attacks. Cybersecurity, then, is a technology that has cross importance for managing all the challenges of

the transformations towards digitalization and servitization.

In the light of the above-cited considerations, next section reports a model for jointly managing the servitization transition through new technological advancements.

4. Model for digital service transformation

Digital and Key Enabling Technologies can have beneficial effects in overcoming the challenges that the servitization process presents. Moreover, the exploitation of smart technologies to support servitization could lead to new business models and opportunities for companies. In particular, this joint evolution could enhance the provision of PSS to a new and enhanced level, i.e. “Smart Product-Service Systems”. Figure 1 represents the envisioned model.

The *x-axis* stands for the journey from product to service as formalized by (Tukker, 2004). Starting from the traditional offer of pure products to a pure service perspective. As previously hinted, the shift from product to services also implies a change from transactional to relational approach toward customers (see this change in the upper part of the figure). In the middle of product and services, different solutions of product-service systems are presented. In particular, three categories are adopted: product-oriented services, use-oriented services and result-oriented services. Product-oriented approach implies offering services that are strictly connected to products, such as maintenance activities. In the use-oriented and result-oriented approaches, the PSS supplier still keeps the ownership of the product and the customer pays for the use of it or in relation to a functional result that is delivered by the product. The final step on the *x-axis* represents the business model based on pure services, where the product is not relevant anymore and the value is based completely on the service.

The *y-axis* represents the duality of physical and digital reality. Industry 4.0 technologies enable the possibility to provide a digital environment in which real objects are reproduced. These objects could be either simple products or whole factories. Digitalization provides many tools that are specific to the design of products, processes and production systems (Tolio et al., 2013). Moreover, the possibility to connect each equipment in the factory with sensors enhances the development of virtual factory models, supporting production control and optimization. Simulation tools, for example, are able to provide decision support and can be successfully combined with data analytics, which is one of the pillars of the Fourth Industrial Revolution (Shao et al., 2014).

The model presented in Figure 1, represents the combination of the digitalization and servitization paths suggesting three new solutions, that are named: smart products, smart PSS and smart services.

Starting from the product transformation (referring to section 1 and 2 of the model), the opportunity of a broad use of sensors and IoT technologies gives the capability to the products and processes to communicate in real-time

with other entities in the factory. Smart products cannot only identify themselves but can also give updated information in their entire lifecycle (Schmidt et al., 2015). This enables a real-time control for the status of the products, which can be understood as final goods manufactured and tracked from the production to the delivery to customers, but also as machines and equipment used in the factory. The outcome of introducing sensors is the full traceability of the status of products and processes in the factory, enabling the PSS provider to monitor the solution through the entire lifecycle (West et al., 2015). The competitive advantage in offering smart products instead of traditional ones is the possibility to include them in a connected environment,

enhancing the storage and the analysis of the data they are able to collect for optimization purpose. To better understand the model depicted in Figure 1, we will consider the example of a company supplying an assembly line to an original equipment manufacturer. Traditionally, a production line is sold to the customer that is in charge of installation and management of the line during the whole lifecycle (section 2). To make the product smarter, the supplier can equip the line with sensing and communication technologies, via Ethernet or Wireless solutions, growing the value of the product that is owned by the customer, who can also connect it to the information system or to other equipment in the factory (section 1).

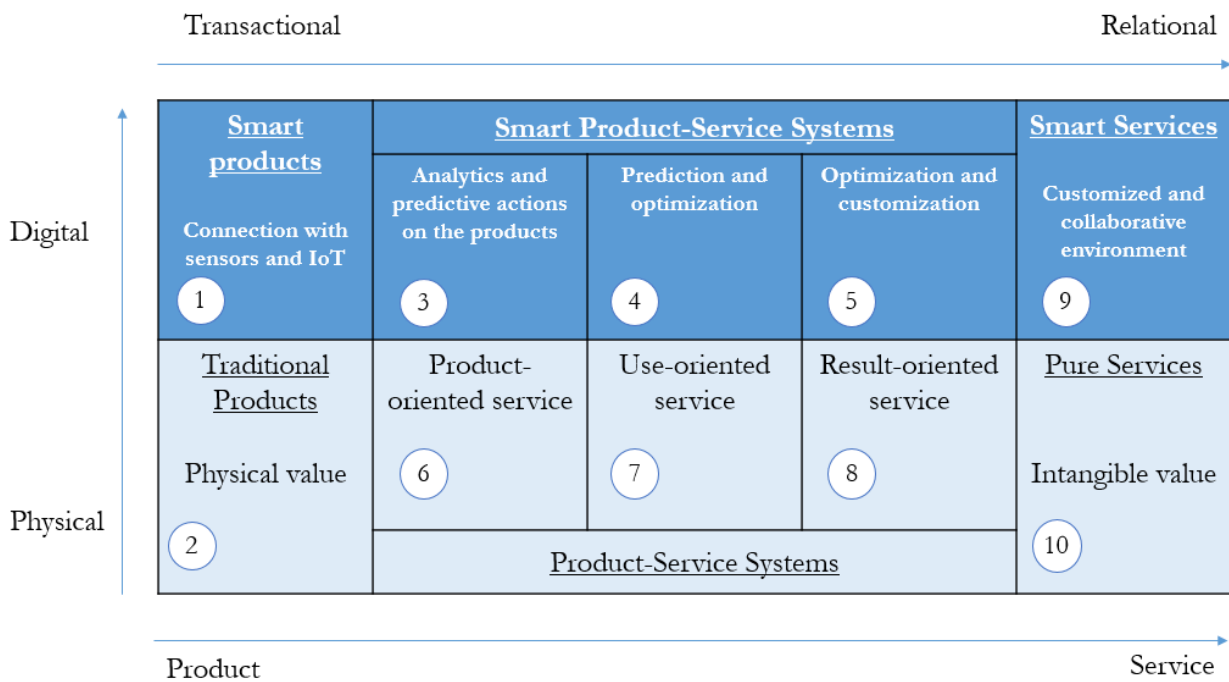


Figure 1: The servitization-digitalization model

The next step in the journey towards servitization and digitalization is depicted in the sections 3, 4 and 5, where three solutions of digital PSS are represented. In the first case, which is the product-oriented approach, the introduction of digitalization can improve the traditional services that are offered to customers (e.g. maintenance) introducing predictive approach. In fact, as described previously, embedded sensors and IoT can transform products and equipment into Cyber-Physical Systems (CPS) that are self-aware and able to self-assess its own health and degradation (Lee et al., 2014).

Considering the example of the assembly line, in the traditional offering (section 6) the supplier of the line can deliver some product-related services to the customers such as maintenance activities. Traditionally these maintenance activities can be done at fixed time interval as suggested by a preventive maintenance approach. Being the line transformed into a connected product, it is possible for the supplier to shift to a condition-

monitoring or predictive approach in the maintenance (section 3). The supplier can select a set of critical parameters that can be real-time and remotely monitored and can give an alert when a maintenance activity is necessary. The data collected and communicated from the line can be stored and analysed, in order to extract features to detect, in advance, fault occurrences (Lee et al., 2014).

These advanced capabilities in the products can upgrade the PSS offering also for use-oriented and result-oriented approaches, which are represented in sections 4 and 5. In particular, the real-time analysis of the functioning of the machines allows the supplier to offer optimized services, which can satisfy the customer requirements of reliability and efficiency, saving costs for the supplier.

In the case of the assembly line, we can suppose that in a traditional PSS (section 7), the customer has a contract based on pay-per-use and leases the machine from the

supplier, who is in charge of maintaining the line in order to provide the desired reliability. Taking advantage of predictive analytics, for example, the supplier can improve its intervention on the production line, limiting the costs of maintenance and providing a service that still meets the requirements of reliability of the customer, but with optimized use of resources in terms of direct and indirect maintenance costs (section 4). Moreover, considering that the customer can have a contract in which the remuneration of the supplier strictly depends upon the results of the machines (section 8) that can be measured with industrial Key Performance Indicators (KPIs), the digitalization of maintenance information can be even more critical in supporting the supplier to offer better services. In a long-term perspective, the optimization of maintenance has a great potential in extending the life of the equipment, enabling a tight relationship with customers and the customization of services based on the actual use of the product supplied. From a supplier perspective, the monitoring of the real use of its products can empower the engineering of more efficient solutions. The feedback from the shop floor, in the case of the assembly line, can be used for improving the design of the line, achieving the end-to-end engineering integration along the value chain (Figure 2). This is a central topic in the smart manufacturing paradigm, as it has been discussed in the first “Recommendations for implementing Industry 4.0 strategies” (Kagermann et al., 2013).



Figure 2: End-to-end engineering along the value chain
(Source: Kagermann et al., 2013)

Finally, in section 9 and 10, the digitalization of pure services is considered. A service is described as “an activity done for others with economic value and often done on a commercial basis” (Baines et al., 2007). Generally, digitalization enables new channels to deliver services, mainly exploiting cloud-based solutions. The availability of technical applications remotely accessible from different stakeholders allows the creation of collaborative platforms for customers and suppliers. The potentials of cloud-based platforms open a variety of opportunities for providing a full digital ecosystem (Geissbauer, R. et al., 2016) facilitating transactions and operations. Co-design for complete customization, horizontal integration of logistics and digital sales and marketing are some examples of practical advantages offered by platforms to push customers and suppliers to a closer position.

Overviewing the example of the assembly line, it can be realistic to consider that the supplier can provide to the customer training service for the operators that will be allocated to work on the line (section 10). The training is a pure service delivered conventionally with human

resources from the supplier, using paper support material (e.g. handbook and data sheets). Moving to a digital platform (section 9), training services can be delivered online within an interactive environment, also exploiting augmented reality or virtual reality technologies. In this way, the operators that attend the training have the possibility to learn with a better perception of the real functioning of the line, interacting with 3D objects (Syberfeldt et al., 2016). Furthermore, the supplier can save money providing support and material remotely, without the need to make a time-consuming and cost-demanding training on site.

The proposed framework highlights the plethora of possibilities that the adoption of digitalization and advanced technologies can have for the provision of advanced PSS and the overcoming of the servitization challenges. The implications of such evolution are many and possible further developments can also be mentioned. In next paragraph, the implications of the described model will be discussed.

5. Discussion and conclusion

The model presented in the previous section offers a structured view of how to combine the servitization process with the new trends of digitalization and smart manufacturing. As a matter of fact, it is possible to underline that going through such a complex business transformation can bring great benefits for companies, but can also present several issues and challenges. First of all, companies need to change their entire business models. Referring to the business model canvas of (Osterwalder et al., 2005), it is possible to identify for each building block some variations that are produced by the implementation of Industry 4.0 technologies. For instance, the value proposition, that is the core of the business model, is affected by the possibility of changing or updating the offering of products and services based on the customer needs and preferences. Value configuration, distribution channels and partners networks can change as well (Arnold et al., 2016). Thus, it appears clearly that the transformation suggested by the Industry 4.0 paradigm is primarily related to the business model innovation that leads companies to increase the value creation through the enhancement of their product-service offerings.

Vendrell-Herrero et al., (2018) present a taxonomy of digital business models, identifying digital servitization as one important opportunity mainly for digital non-native firms. Moreover (Coreynen et al., 2017) present three different servitization paths that exploit digital technologies and report the barriers to such transformation. Among them, it is possible to mention the difficulty in estimating the return on investment and the complexity of introducing new services tangible for the customers, who are usually reluctant towards changes (Coreynen et al., 2017).

The changes into the business model are not limited to the value proposition but they also impact the company resources and organization since the development of new sales competencies and the improvement of customers interfacing skills is required. Hence, it is commonly

recognised that there is an increasing need for technical and social competencies of the employees. (Romero et al., 2016) identify different typologies of Operators 4.0, suggesting several augmentations of the humans using smart technologies. Actually, the journey towards servitization and Industry 4.0 needs to be combined with a clear roadmap to transform and improve the competencies of workers. For this purpose, re-skilling and up-skilling of workers are necessary, because the introduction of automation will displace routine tasks, while the humans will still have the responsibility of managing complex and cognitive tasks (Waschull et al., 2017). Therefore, humans have a central role in the business transformation and one of the challenges that both servitization and Industry 4.0 present is the cultural change that is required to succeed. Accordingly, a limitation of the model described in section 4 is that competencies and human value are not considered. As a consequence, further research would provide a more exhaustive version of the framework including business models and competencies will be combined.

Finally, considering the implications of the model from a company perspective, it is essential to mention that the suggested framework proposes the broadest range of possibilities that an enterprise can exploit from the implementation of digital technologies and servitized business model. Therefore, the choice of how to position the own attitude of the enterprise need to carefully evaluated in relation to its characteristics and practical opportunities to improve the revenue streams while maintaining high efficiency and flexibility.

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