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Industry 4.0 data-related technologies and servitization: a systematic literature review

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Abstract. The advancements and adoption of digital technologies enable manufacturers to approach intelligent production and reach a higher level of automation in the wave of Industry 4.0. Even though manufacturing is at the center of this industrial revolution, the impact of digital technologies is more far-reaching: indeed, one of the biggest growth potentials is recognized in the paradigm shift from a traditional product orientation to the provision of bundled solutions. Particularly the possibility to gather and analyze data has been recognized as a key enabler for the advancement of the product-services offering. In this view, the research presented a systematic literature review exploring the state of the art considering on one side the newest technologies related to data and digitalization and on the other side servitization, aiming at understanding the point of contact between them. Four different perspectives have been identified and discussed and possible research directions have been proposed.

Keywords: Digital technologies, Servitization, Industry 4.0, data-driven

1. Introduction

Originated in Germany in 2011, the term “Industry 4.0” refers to a paradigm shift from automated manufacturing toward an intelligent manufacturing concept, enabled by the adoption of digital technologies and associated paradigms, to achieve a higher level of operational efficiency and productivity, as well as a higher level of automation [1]. Even though manufacturing is the main focus, the impact of Industry 4.0’s technologies is more far-reaching: indeed, one of the most significant growth potentials is recognized in the paradigm shift from a traditional product orientation to the provision of bundled solutions [2]. The concept that manufacturers need to leverage innovative combinations of services and products to increase the scope of their value creation activities and to face the increasing global competition is not new. There is a rich literature on this trend, which has been mainly discussed under the terms “Servitization” and “Product Service System” (PSS) [3]. Moreover, the advancements in the technologies that allow obtaining real-time data from the environment and act upon this to control, monitor, and interact with the real world are supporting and revolutionizing the “Servitization” trend. In this regard, Information and Communication Technologies (ICT), Internet of things

(IoT), cloud computing, data analytics, and the possibility to integrate information along the value chain in real-time, are the most relevant technologies [4]. The adoption of these digital technologies is a key enabler for the provision of many services related to an integrated solution, either i) supporting new functionalities, ii) providing the possibility to offer “Smart Services” or iii) increasing the efficiency of service delivery [2]. For example, connecting products enable manufacturers to provide services such as predictive maintenance and remote control from center for remote-controlled operations. Additionally, the adoption of an intelligent ICT infrastructure enables gathering feedback and data collection from later stages back to the earlier stages of the product lifecycle [5]. It creates the potential to enhance the value co-creation process, which is one of the central premises of the service logic [6]. In this view, this research aims at exploring state of the art in the above-mentioned fields and understand the point of contact between Industry 4.0 and Servitization. To this end, we adopted a broad perspective including both researches that are focused on the “digital servitization” stream, and papers that are focused on the technological and industrial perspective that is not always covered into the servitization domain [7].

The paper is structured as follows: Section 2 delineates the methodology followed to perform the systematic literature review, Sections 3 and 4 report some quantitative analysis of the final sample and the categorized papers considering their content. In the end, Section 5 discusses some insights into the analysis proposing possible future research focus and concludes the work.

2. Methodology

The systematic literature review has been identified as the best option to pursue research’s aims, since it is widely used to explore an emergent topic, investigate the advancement of a specific stream of research as well as to propose recommendations for future studies [8]. A systematic review can be distinguished from different types of publications for its scope and rigorousness. Indeed, a rigorous scientific investigation follows a specific, explicit and, therefore, reproducible methodology and approaches to identify, collect, evaluate and discuss relevant issues on the specific topic [9] limiting bias and random errors [10]. Approaching systematic literature review requires a specific protocol: to this end, we decided to follow the PRISMA statement, which defines a detailed set of steps to be followed during the systematic literature review [11]. In this research, the four main steps, which are (1) identification, (2) screening, (3) eligibility and (4) inclusion have been addressed. All steps followed by authors are described in the following paragraph.

In order to identify a representative corpus of documents for investigation, the first step was the definition of a set of keywords to be included in the research. For each keyword, the specific meaning of the word or concept has been defined as well as a set of synonyms to be included in the query.

The keywords have been chosen separately for the two different topics. For what concerns “*Industry 4.0*”, authors considered only concepts related to the possibility to gather data and enable the data utilization. Particularly, six technologies have been selected, as reported in Table 1. For “*Servitization*”, two main research streams have been

found in the literature, that express a similar concept: Servitization and Product Service System.

Table 1. *Keyword selection – Technology domain*

Keyword	Reference
Internet of Things	[12]
Internet of Services	[13]
Digitization	[14]
Analytics	[15]
Big Data	[16]
Cloud Computing	[17]

After the definition of the keywords, the research was performed using the Scopus database, and the queries have been constructed linking two by two the different concepts: a total of six queries has been used, matching one concept from technologies domain and one from servitization. Screening has been addressed by limiting each query to the English language and year of publication after 2011 since the Industry 4.0 concept emerged in 2011. Moreover, to limit the scope of the research, the subject areas included were: Engineering; Computer Science; Business Management & Accounting and Decision Science. Because of the high number of papers related to those queries, the research was limited to articles published in journals. This choice allows also to have control over the quality of publications [9]. In the end, each query was defined as explained in Table 2, searching the specific keywords in the papers' title and abstract.

Table 2. Query definition

Service perspective	(1)	((TITLE-ABS-KEY (pss*) OR TITLE-ABS-KEY ("Product-Servi* System*") OR TITLE-ABS-KEY ("Integrated product servi*") OR TITLE-ABS-KEY ("Industrial Product servi* System*") OR TITLE-ABS-KEY ("Integrated Product Servi* Offer*") OR TITLE-ABS-KEY (ipso) OR TITLE-ABS-KEY ("Integrated Solutio*") OR TITLE-ABS-KEY ("Product servi*")))
	(2)	((TITLE-ABS-KEY (serviti*ation) OR TITLE-ABS-KEY ("Smart service") OR TITLE-ABS-KEY ("Servi* Infusion") OR TITLE-ABS-KEY ("Hybrid Value Creation") OR TITLE-ABS-KEY ("Service-oriented Manufacturing") OR TITLE-ABS-KEY ("Customer Solution*") OR TITLE-ABS-KEY ("Product-extension service*") OR TITLE-ABS-KEY (demateriali?ation*)))
Technology per-	(3)	((TITLE-ABS-KEY ("Big Data") OR TITLE-ABS-KEY ("Cloud Computing") OR TITLE-ABS-KEY (digiti?ation) OR TITLE-ABS-KEY (analytic*)))
	(4)	((TITLE-ABS-KEY (ios) OR TITLE-ABS-KEY ("Internet of Serv*")))
	(5)	((TITLE-ABS-KEY ("Internet of Thing*") OR TITLE-ABS-KEY (*iot) OR TITLE-ABS-KEY ("Internet of Everything") OR TITLE-ABS-KEY ("Industrial internet of thing*") OR TITLE-ABS-KEY ("Industrial internet")))
		(1)AND(3); (1)AND(4); (1)AND(5); (2)AND(3); (2)AND(4); (2)AND (5)
AND		(LIMIT-TO (LANGUAGE, "English "))
AND		(LIMIT-TO (SUBJAREA, "ENGI ") OR LIMIT-TO (SUBJAREA, "COMP ") OR LIMIT-TO (SUBJAREA, "BUSI ") OR LIMIT-TO (SUBJAREA, "DECI "))
AND		(LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) R LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011))
AND		(LIMIT-TO (DOCTYPE , "ar "))
AND		(LIMIT-TO (SRCTYPE , "j "))

The final pool of paper resulted in the aggregation of the results from the six different queries, therefore duplicate removal has been performed. Then, in addition to the filters described in the research query, authors have perused articles in three different rounds, increasing the level of the content incrementally under analysis. First of all, titles have been read, then abstract reading enabled to further restrict the pool and in the end, full texts have been examined. Not all the full-text readings have led to a positive inclusion in the final pool since some works did not meet the eligibility criteria. Thus, a first reading was made to decide the level of coherence and adherence of the content with the scope. Papers have been excluded for two reasons:

- (1) The degree of technology innovation cannot be included in the wave of industry 4.0, even if the paper was focused on servitization and technological advancement;
- (2) High technological applications and topics were completely disjoint from the service-oriented perspective, and it was not even possible to assume that those solutions would be used as service applications.

In Fig. 1 all steps and the corresponding number of papers are reported.

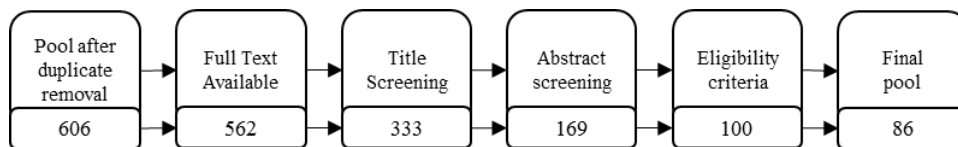


Fig. 1 – Steps and number of papers along the systematic literature review

3. Papers descriptive analysis

The first analyses investigated the corpus of the review considering some “demographic” analysis. Specifically, it is possible to notice an interesting increment and constant growth of the number of publications from 2016, as depicted in Fig. 2, proving an ongoing interest in the research field in recent years.

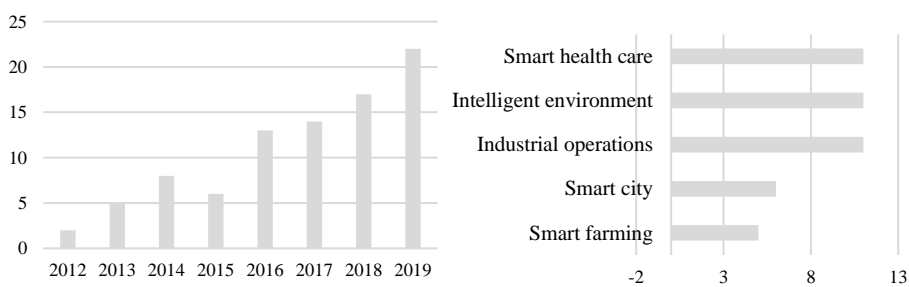


Fig. 2 – Number of publications over years Fig. 3 – Top five applications field (n. of paper)

An analysis has been also performed on the journal source: it revealed that they are widespread from technology, management, service, marketing and other fields and most of them have a technical imprint, as it is possible to see in Fig. 4. The most recurrent journal is the “Journal of ambient intelligent and smart environment” meaning that

in the field of Smart Environment the topic is highly debated. Looking at the application field that papers deal with, there is no doubt that the intelligent environment has a core position. It refers to the capacity of sensing of ambient with respect to different factors and the consequent ability of the system to offer services based on necessity, either adapting or calling some “external entities”[18]. Nevertheless, as it is possible to see from Fig. 3, there are not borders in terms of applicability: Smart health care, Industrial operations, Smart city and Smart farming are also at the center of the discussion.

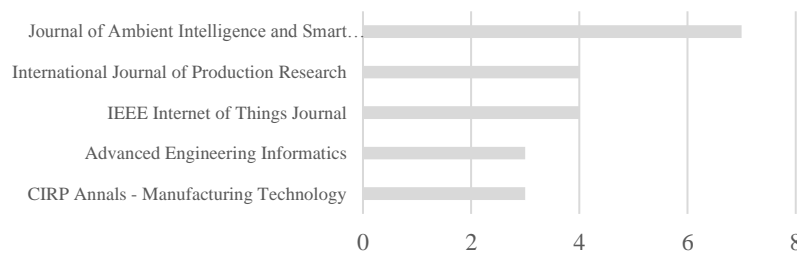


Fig. 4 – Top 5 journals in the pool (n. of paper)

4. Paper categorization

At the starting point, the final corpus of paper resulted to be heterogeneous since the topic is widespread among different disciplines. Consequently, we decided to categorize papers into homogeneous groups to provide an overall overview of the topic. The categories have been established considering on one side the focuses introduced with the keywords that are related to the service domain and technologies, and on the other side, the most relevant perspectives underlined by the literature.

As mentioned in the introduction, digital servitization is a research stream already established. It focuses on the company service transformation as the core aspect, considering technological advancement that are completely reshaping the way firms offer services [19]. Digital servitization has been studied under different perspectives, generally highlighting the value that digital technologies can provide for the service value delivery to the customer. In particular, some studies demonstrated that digitization facilitates the development of cost-efficient operations and is an enabler of service quality through better resource allocation and more accurate information sharing inside and outside the boundaries of the firm [20]. In accordance with that, attention has been focused by different academics into the integration of servitization and digitalization with other business dimensions, as the manufacturing process and the supply chain. The production perspective emerges, for example, in the work of Coreynen et al. (2017) [21]: they examined how digital technologies can enable different Servitization pathways proposing three different cases, that are Industrial, Commercial and Value Servitization Pathways. Into the Industrial pathway, resources and capabilities are devoted to make the internal manufacturing operations smarter and provide new hybrid services for the customers. For what concern supply chain, for example, Vendrell-Herrero et al., (2017) study how the dematerialization of physical products is transforming the way firms are positioned in the supply chain and their engagement with customers. [22]

Starting from these considerations, authors divided the corpus of the paper according to three different focuses, that are the *service*, the *industry* and the *supply chain*. Lastly, a final class has been defined to represent research studies describing from a technological point of view some specific applications based on Industry 4.0 technologies that could potentially be deployed as a service in many circumstances.

The classes have been named: (CL1) Digital servitization transformation; (CL2) Industrial servitization of operations; (CL3) Supply chain and network collaboration; and (CL4) Technological focus in specific applications. Table 3 reports the number and the papers per each category.

Table 3. Number of papers per categories and references

ID	Classes	N of papers	References
CL1	“Digital servitization transformation” Papers that deal with digital servitization transformation	25	[7], [21]-[44]
CL2	“Industrial servitization of operations” Papers presenting digital technologies, resources and capabilities to make the internal manufacturing operations smarter with adopting concept of servitization	10	[45]-[54]
CL3	“Supply chain and network collaboration” Paper dealing with the impact that the adoption of new technologies has on the collaboration practices in the value chain and implications at the network level”	10	[55]-[64]
CL4	“Technological focus in specific applications” Papers dealing with the realization of a systems or application towards smart service provision for the technological point of view.	41	[56]-[96]

CL1 has been created considering papers that deal with digital servitization transformation. This pool represents works studying different aspects of the path of manufacturing companies thought the servitization paradigm leveraging the possibilities that technologies and data gathering are creating. What emerges is that the scope of the services is changing and expanding. Particularly, has been found that products connectivity enables manufacturers to offer new services with new service value proposition [24]. The manufacturer has the possibility to continuously auditing customer operations and expand value creation having the ability to operate within the field of product use including services at customer’s operation level [41]. Moreover, if the applications are into business context, the need of a culture of trust with business partners, customer and users emerge more and more, since customers have no intrinsic interest in sharing operational data with machine tool contractor and to hook them up to their data gathering and processing systems[41], because of different privacy and security issues. In this view, value creation and co-creation, which considers the necessity of the customer involvement and engagement into a joint-value creation process [24], are recognized as the basis of the deployment of such solutions. CL2 deals with applications that employ digital technologies, resources and capabilities to make the internal manufacturing operations smarter. Among them, an interesting part considers the cloud manufacturing

paradigm as the main impact of service-oriented applications. Indeed, customers can have access to on-demand services, such as engineering design, simulation, production, assembling, testing and management.[51]. Some other works deal with the Industrial Product-Service System (IPSS), as an approach to operate in an efficient and effective service-oriented way, enhancing life cycles, delivering solutions that meet customer expectations, providing, for example, a tool to support firms into the decision of an IPSS adoption [52]. CL3 is focused on the positive impact that the adoption of new technologies has on the collaboration practices in the value chain and on the other on the implication at the network level. From the analysis resulted that the adoption of intelligent products and the contribution of ICT enhancement can result in the integration of users together with producers and service providers in closed data and information loops, in a collaborative ecosystem. Inside those works, it is possible to find paper dealing with models supporting a service-oriented enterprise collaboration network [58] or describing the benefits of the Internet of Things (IoT)-based systems into the supply chain context [59]. CL4 is the larger class and the most widespread among different disciplines and fields. Within this class, it is possible to find papers that, for example, describe the realization of a smart service system set up for the maintenance, remote failure diagnosis, quick service response, failure detection and iterative optimization of sugarcane harvesters [89]. Other works describe IoT hybrid monitoring systems for health care environments providing location, status, and tracking of patients and assets [91]. Another proposes a Smart Service Orchestration Architecture to coordinate ubiquitous objects, create interlinked data, and implement versatile smart service in the Smart City context [99]. Within this class, it is possible to find also works that are more focused on the manufacturing side [93] or supply chain and coordination mechanisms [66] [87]. Overall, it is possible to state that with different perspectives and field of applications lot of paper deals with the design and development of complex solutions, which needs the technological competences in the realization of infrastructure, that should be reliable and secure, analytics capabilities and the know-how into the field of applications.

5. Discussion, conclusion and future research

This work is concerned with the interconnection between two main emerging phenomena: the Industry 4.0 technologies related to the data domain, and the Servitization. From the analysis of the corpus of the papers, it was possible to draw out first insights, considering that different focuses have emerged, that are: (CL1) Digital servitization transformation; (CL2) Industrial servitization of operations; (CL3) Supply chain and network collaboration; and (CL4) Technological focus in specific applications. Inside those classes, a deeper analysis needs to be performed, as a natural development of the proposed work. Nevertheless, some possible direction emerges from this initial analysis. From this review, it is possible to notice how the two phenomena under investigation maintain separate knowledge and research stream, indeed, as also highlighted by Frank et al., (2019) [7] the connection between Servitization and Industry 4.0 is still emerging. There are some initial attempts of merging but authors maintain most of the time the two concepts disconnected, indeed most of the studies into the CL1 do not

consider the manufacturing perspective, while into the other three classes the servitization perspective is weakly addressed. Moreover, even though authors included in the research keywords several concepts related to the possibility to gather data and enable the data utilization, the specific focus on data remains poorly covered in the pool of paper and mostly appears as an underlying enabler. Indeed, studies either focused on the impacts of technologies on service offering (CL1) or on the technical development of solution (CL4), without proposing a holistic view. There is a lack in the overall comprehension of data-related services, both considering their characteristics and development. Additionally, even studies reveal how the information sharing among firms create the potential for collaboration that enables more efficient operations, as emerged both in CL1 and CL3 there are limited works that further investigate value creation mechanisms in a data-enabled ecosystem. Consequently, considering the possibility to further integrate the relation of data technologies and possibilities into the service point of view and vice versa, some interesting direction emerges. Those directions are the result of a cross-analysis of the different classes, not considering what can be done for each of them, but how to move forward to create synergies between them and blurring the boundaries among different pieces of knowledge.

Research direction 1: The creation of a systematic understanding and synthesis of the possibilities that technologies and data availability open in the service field should be addressed, as well as an analysis of value creation practices considering data-related applications. A contribution can be made by means of taxonomies or classification frameworks both regarding service typologies, value proposition and value creation mechanisms that may be achieved from data collection and analysis.

Research direction 2: Structured approaches that enable firms to leverage data to create value, both for customers and for internal applications can be formalized. Those approaches should also be considered to fill the gap that emerges clearly between the technological perspective and the servitization perspective, providing tools and methodologies aiming at synergistically address both domains. Service Engineering methodologies may be proposed, considering including data-driven and industrial lenses.

Research direction 3: New cooperation and collaboration mechanism need to be analyzed and conceptualized to support firms and all actors in this transition. Particularly the ecosystem perspective should be included considering access and sharing of resources, including knowledge, capabilities but also data streams. In particular, the digital ecosystem that characterizes the majority of data-driven services may be analyzed from a platform perspective, that strongly emerges as the tool which supports data collection and analysis as well as application deployment, considering how the design of the technological architecture impact the value creation for different actors.

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https://docs.google.com/document/d/11WOy80T4pSWpoT_1yIF19GH2F6VXsUw0nkXT2FujjCU/edit?usp=sharing

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