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Research paper

Digital servitization in manufacturing: A systematic literature review and research agenda

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ABSTRACT

This paper addresses how servitization is facilitated by the adoption of digital technologies and presents a review of the literature on this subject. The paper aims to characterise the phenomenon of 'digital servitization' by examining how the literature describes the convergence between servitization and digital technologies as well as to identify areas for future research developments. The systematic review of the available scientific literature revealed limited but rapidly growing coverage of the phenomenon by scientific studies, which have mainly focused on the role of a few digital technologies (above all, the Internet of Things), studied in isolation. The research has mainly adopted an empirical, case-based methodological approach, mostly investigating the industrial equipment, automotive, and IT industries and focusing on the role of digital technologies for the implementation of intermediate and advanced services. This picture calls for future research endeavours to extend the scope of investigation into digital servitization (regarding the technologies covered and their combinatory effect, the potential benefits, and the application domains) and to develop models and frameworks to support decision-making by practitioners.

1. Introduction

The phenomenon of servitization was originally identified by Vandermerwe and Rada (1988). It describes the shift from selling products to offering 'bundles' of customer-focused combinations of goods, services, support, and knowledge in delivering value in use. Current servitization literature points to a number of opportunities for manufacturers. Notably, it is considered a strategic alternative to product innovation (Carlborg, Kindström, & Kowalkowski, 2014) and standardisation (Baines et al., 2007), a means to deal with commoditisation (Matthyssens & Vandenbempt, 2010), and a method of building unique, loyal customer relationships (Tukker, 2004). Manufacturers consider servitization a key strategy because of its financial (Neely, 2008), strategic (Baines & Lightfoot, 2014; Kowalkowski, Gebauer, Kamp, & Parry, 2017) and marketing (Gebauer, Saul, Haldimann, & Gustafsson, 2017) benefits, which capture additional value in their existing product offerings. Servitization is evidently a complex field with contributions arising across a range of research communities that are interdependent.

Servitization has always involved technologies (Rabetino, Harmsen, Kohtamäki, & Sihvonen, 2018) that shape its strategies, processes, and structures. Despite the fact that servitization and digital technologies originate in different research fields (the former in management and the latter in engineering and computer science) (Díaz-Garrido, Pinillos, Soriano-Pinar, & García-Magro, 2018; Liao, Deschamps, Loures, De, & Ramos, 2017), scholars argue that a strong link exists between them (Vendrell-Herrero, Bustinza, Parry, & Georgantzis, 2017). Recent research suggests that the application of digital technologies can further advance servitization by enabling sophisticated and novel service offerings (Grubic, 2018; Lerch & Gotsch, 2015). In fact, the adoption of technologies such as Internet of Things (IoT) analytics and artificial intelligence can empower or completely transform the features of delivered services (Ardolino et al., 2018; Holler, Tsiatsis, & Mulligan, 2017; Rymaszewska, Helo, & Gunasekaran, 2017) and enable new service-oriented business models (Adrodegari & Saccani, 2017), consequently reshaping industry competition (Porter & Heppelmann, 2014). Indeed, product-centric companies introduce digital technologies to increase service delivery efficiency and the value of product-service offerings while simultaneously changing processes and business models (Candell, Karim, & Söderholm, 2009; Lerch & Gotsch, 2015). Industrial cases such as Rolls-Royce (Parida, Sjödin, Wincent, & Kohtamäki, 2014), General Electric (Evans & Annunziata, 2012), and Kone (Ardolino et al., 2018) have shown how new business models and smart services can be delivered with high efficiency and effectiveness

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through the use of digital technologies. For instance, Rolls-Royce's program, 'Power-by-the-Hour', is a servitized business model in which airline manufacturers pay a fee for the use and availability of engines instead of buying them. Furthermore, Rolls-Royce has implemented IoT technologies to monitor engine data in real time in order to effectively provide maintenance (Baines & Lightfoot, 2013), whereas General Electric, with the support of analytic tools, developed the necessary capabilities (e.g., processing, analysis, and interpretation of data from the installed base) to provide remote monitoring services.

Conversely, the topics of servitization and digital technologies in manufacturing have been researched partly in isolation. The convergence of these two phenomena has only recently emerged under the name of *digital servitization* (Bustinza, Gomes, Vendrell, & Shlomo, 2018; Vendrell-Herrero et al., 2017). Thus, a more focused research effort is needed to better understand digital servitization – a relatively new stream of study (Grubic & Jennions, 2018; Kowalkowski, Kindström, & Gebauer, 2013). This paper addresses this digital servitization phenomenon and aims to collect evidence from the literature, which is quite sparse in the various related research fields. Based on a systematic literature review, the paper aims to systematise the scientific knowledge of the phenomenon and set directions for research. Our SLR aims at covering how all the identified digital technologies (Section 2.2) enable servitization. Our approach, therefore, differs from previously conducted literature reviews that tended to focus solely on one topic at the interface between digitalization and servitization, such as that of Grubic (2014), in which a review of servitization and remote monitoring technology is presented, and that of Luz, Peña, Díaz, José, and Sánchez (2018), which is focused on new digital business models. Therefore, the following research questions are addressed in the paper:

RQ1. To what extent does digital servitization find consideration in current literature and how is it characterised?

RQ2. What are the main research directions suggested by the analysis of the literature?

This article is structured as follows: Section 2 describes the research methodology used in the study, which is followed by a descriptive and thematic analysis in Section 3. Thereafter, Section 4 discusses the findings and presents a list of future research avenues for digital servitization. Finally, Section 5 provides implications for research and practice and presents the limitations of this paper.

2. Research methodology

2.1. Search strategy

In order to answer the research questions, we conducted a systematic literature review to collate all the relevant evidence that fits the pre-specified eligibility criteria. This systematic literature review was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) approach (Moher et al., 2015). The PRISMA methodology entails an evidence-based checklist linked to a four-phase flow diagram and ensures clarity and transparency when reporting systematic literature reviews. With the use of the PRISMA method, bias is limited, chance effects are reduced, and the legitimacy of the data analysis is enhanced (Fig. 1).

In the first phase, we developed the review protocol, review questions, and search strategy. Based on the overarching research questions above, a number of review questions were suggested to focus the enquiry further:

a) What are the characteristics of the current body of literature on digital servitization?
b) What is meant by digital servitization and how is it commonly defined?
c) What benefit does it offer to customers, providers, and other stakeholders?
d) Which digital technologies enable different service categories, and how is this achieved?

2.2. Inclusion and exclusion criteria

The development of search keywords was then guided by the questions above. Two sets of keywords related to the concepts of servitization and digital technologies were selected and used in combination. The first set of keywords was related to servitization in manufacturing companies and included 'servitization', 'servitisation', 'product (-) service system* (PSS/IPSS)', 'integrated solution*', 'service transformation', and 'service infusion'. It is worth noting that the choice of these keywords was based on the keywords used by Baines et al. (2007). The second set of keywords was based on the use/adoption of digital technologies in business contexts. A plethora of research (scientific and grey literature), several governmental programs, and at the forefront, the diverse national initiatives related to Industry 4.0 have addressed the adoption of digital technologies for the innovation and digital transformation of manufacturing companies. We analysed these classifications and harmonised the terminology for digital technologies (see Table 1) to serve the purposes of our study on digital servitization. A more detailed list of the classifications analysed can be found in Appendix A.

The digital technologies listed in Table 1, with their synonyms and other related representative terms, were used to outline the second set of keywords: '3D printing', 'additive manufacturing', 'advanced manufacturing solutions', 'artificial intelligence', 'autonomous robots', 'big data', 'analytics', 'cloud', 'cyber security', 'horizontal and vertical integration', Internet of Things (IoT)', 'simulation of connected machines', 'virtual reality', 'augmented reality', 'mixed reality', and very general terms such as 'digital technologies', 'digital transformation', 'digitalization', 'digitization', 'information and communication technologies (ICT)', 'Industry 4.0', 'digital twin', 'digital*', 'embedded systems', 'machine learning', 'mobile computing', 'network', 'platform', 'predictive*', 'real-time optimization', 'remote*', 'sensors', 'smart manufacturing', 'technology/−ies', 'virtual reality' and 'wearables'. As a search interval, the time span between 2000 and 2018 was considered, based on (1) the recentness of both of the examined trends, namely servitization and digital transformation, and (2) the study's goal to scrutinise a sufficiently long time period. To locate relevant articles, the Scopus search engine was used, which is widely acknowledged as a world-leading source that provides comprehensive coverage in this research field (Burnham, 2006; Grubic, 2014) and has been widely used in relevant studies in the field (Baines, Lightfoot, Benedettini, & Kay, 2009).

2.3. Data collection

The next step was to identify the publications and apply practical screening. In this systematic literature review, only journal publications were included, while conference papers, books, company reports, etc., were excluded. In this way, it was ensured that only peer-reviewed articles were considered. In addition, only English-language papers were chosen for analysis. This resulted in the identification of 1169 papers. Upon omitting the duplicates, 997 studies were moved to the screening step. At this stage, 380 studies were rejected, primarily because they were published in journals outside the fields of engineering, business management, operations, services, manufacturing, and life, computer and social sciences. Some examples of the subject areas that were excluded are dentistry, nursing, neuroscience, arts and humanities, medicine, agricultural and biological sciences, pharmacology, immunology and microbiology, earth and planetary sciences, chemistry, biochemistry, genetics, materials science, physics, and astronomy. The titles and abstracts of the remaining 617 papers were screened based on their theme – they had to be related to the convergence of the servitization of manufacturing and digital technologies. The screening resulted in the exclusion of 498 studies, among which were companies'

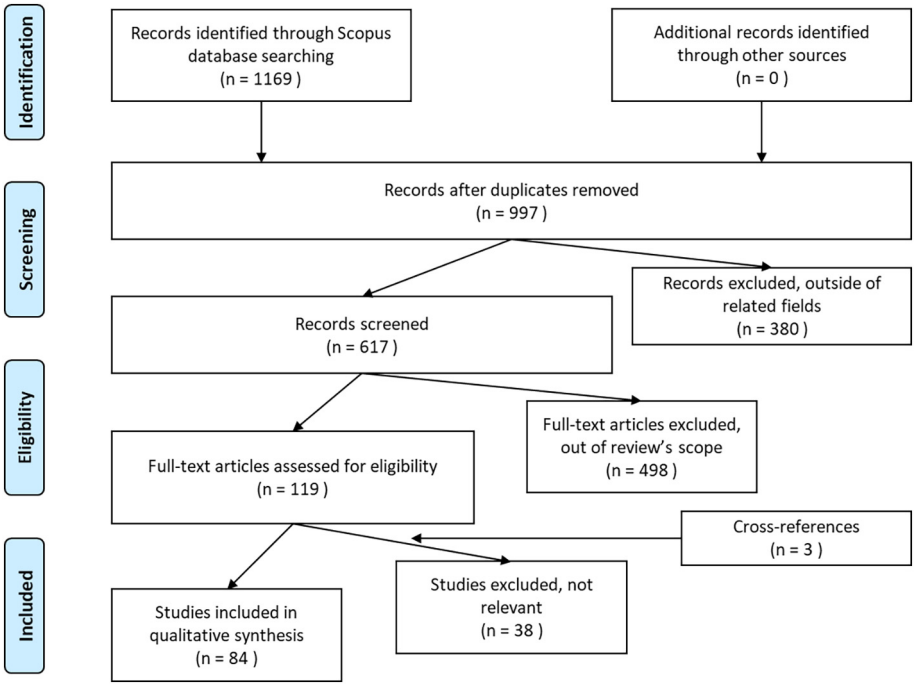

Fig. 1. Flow diagram for the selection of literature reviewed based on PRISMA.

Table 1
List of digital technologies and definitions.

Digital technology	Definition	References
Additive Manufacturing/3D-Printing	This fabrication technique involves the progressive deposition of material onto a substrate, layer by layer, enabling the creation of high-complexity parts that personalised goods require.	(Guoping, Yun, & Aizhi, 2017) (Pfeiffer, 2017)
Advanced Manufacturing Solutions	Cyber-physical systems and collaborative robots that can physically interact with humans in a shared workspace to reach common goals, equipped with sensing technologies that make them aware of contextual conditions and guided/moved by artificial intelligence software.	(Thoben, Wiesner, & Wuest, 2017) (Tjahjono, 2017)
Artificial Intelligence	Simulation of the thinking and behaving process (such as studying, reasoning, thinking, and planning) of human beings. One of the most active niches of artificial intelligence is machine learning that supports preventive decisions.	(Bortolini et al., 2017) (Caruso, 2017)
Big Data and Analytics	Techniques (e.g., statistical analysis, machine learning, neural and Bayesian networks) used to mine and process large structured and unstructured datasets (big data that include numbers, text, pictures, posts, news, videos, etc.) to generate insights, identify patterns, and develop predictive models that are beneficial in a business context.	(Ferreira et al., 2017) (Astrid et al., 2017)
Cloud Computing	Access authorisation from anywhere to a shared pool of computing resources (e.g., servers, storage, and operating systems) that can be conveniently configured and provisioned on demand with minimal management effort.	(Celaschi, 2017) (Santos et al., 2017)
Cyber Security	Control and protection of processes and systems that operate online, identification of changes and vulnerabilities, and verification of authorised users.	(Astrid et al., 2017)
Horizontal and Vertical System Integration	The structural changes in the organisation, the management of physical objects, and the establishment of connections with information systems.	(Liao et al., 2017) (Caruso, 2017)
(Industrial) Internet of Things	The integration of some technological developments whereby products and industrial equipment are connected to provide large datasets and provide insights into the status of the equipment in order to predict other kinds of occurrences and to deliver smart services (e.g., remote control, operations and optimisation, fleet management, spare parts management, and predictive maintenance).	(Xu et al., 2018) (Hofmann & Rüsch, 2017) (Santos et al., 2017) (Suri, Gaaloul, Cuccuru, & Gerard, 2017)
Mixed Reality (Virtual and Augmented Reality)	The merging of real and virtual worlds to produce new environments and visualisations where physical and digital objects co-exist and interact in real time.	(Bortolini et al., 2017) (Celaschi, 2017)
Simulation of Connected Machines	The best option for saving time and resources as it evaluates the changes and behaviors in the configuration of machines, process flows, and plant designs. It also tests the effectiveness of the changes without realising them.	(Bortolini et al., 2017) (Astrid et al., 2017)

journal papers (e.g., *ABB Review*), lecture notes, and publications beyond the scope of our review. For instance, Cáceres and Guzmán (2015) – excluded at this stage – investigate the similarities between the processes of innovation in services and manufacturing; however, although technologies were mentioned in the paper, there is no specific focus on their role and linkages with the servitization domain.

In the subsequent step, the full text of all 119 remaining publications was read in full. Only the articles that were able to contribute to answering the research questions were selected. In addition, the database search culminated in a cross-reference analysis (snowballing) meant to overcome possible keyword search limitations. Three additional studies were thereby identified. In sum, based on the predefined criteria, we selected and analysed 84 papers to systemise the knowledge in this research field and to identify possible knowledge gaps and future directions.

2.4. Data synthesis and analysis

All articles deemed relevant were analysed both descriptively and thematically. In the descriptive analysis, a deductive approach was adopted that focuses on the classification of papers according to the year and journal of publication, number of citations, methodology applied, and industry addressed (if any). Conversely, the thematic analysis was more inductive in nature and designed to characterise the phenomenon of digital servitization. In particular, we aim to 1) conceptualise digital servitization by providing a more complete definition, 2) comprehend its benefits for customers, providers, and other stakeholders, and 3) identify which digital technologies facilitate different service categories and 4) how they do so.

2.5. Descriptive analysis

The 84 papers selected are descriptively analysed in this section with respect to the year of publication, journal, field of study, country, citations, methodological approach, and industrial sector with the aim of identifying trends within this body of literature.

2.6. Temporal, journal, and geographic distribution of the literature

Fig. 2 depicts the time distribution of the papers and the number of citations. With the notable exception of the seminal contribution by Allmendinger and Lombreglia (2005), the papers analysed were all published between 2009 and 2018. In particular, a significant convergence of the two literature streams emerged only from 2015 onwards. More specifically, 59 articles (i.e., 70% of the 84 scrutinised papers) were published between 2015 and 2018, pointing to an increased scholarly interest in the use of digital technologies as a servitization enabler. The growing interest in the digital servitization phenomenon has also been testified to by recent journal special issues on the subject (Bustinza et al., 2018; Loonam, Eaves, Kumar, & Parry, 2018).

To determine the knowledge stocks and flows among scholars, we first analysed how the literature set was spread across different journals. Table 2 presents journals ranked by the number of published papers, their impact factor, and their total citation count (data was computed in July 2019). The journal impact factor (IF) was retrieved from the Clarivate Analytics database (2019). *Citations* refers to the total number of citations of the published studies in each journal up to July 2019. The 84 articles in our database appeared in a total of 54 journals. Only 14 of these journals published two papers or more, showing a high degree of fragmentation of the literature. As an exception, two journals (the *Journal of Manufacturing Technology Management* and the *International Journal of Production Research)* published five articles each.

The journals were also classified according to Scopus database subject area (Table 3). More than half of the papers (published in 29 journals) belong to the engineering sector, while business, management, and accounting (22 journals), and computer science (22 journals) accounted for a considerable number of papers as well. It is worth mentioning that a journal may belong to more than one subject area. Moreover, several other subject areas were represented by fewer papers (such as decision science and social sciences), as reported in Table 3. This trend confirms a rather fragmented picture, typical of a research area that is multidisciplinary in nature and at an early stage of maturity. Additionally, the fragmentation of journals demonstrates that researchers studying this phenomenon have different perspectives and that the subject does not yet have established outlets for publishing.

Authors' affiliations with a particular country helped to provide a picture of geographic trends in digital servitization research. We found that research has been published in 26 countries by 255 authors. Looking at the country representation and based on the affiliation of all authors listed for each publication, the UK leads the ranking with 22 documents, followed by Germany with 15, Sweden with 12, and the US with 10. China and Spain came in next with eight each, Finland and Italy with seven, South Korea with six, and Portugal with four. This is in line with the fact that some countries have a strong tradition in servitization research, such as the UK or Scandinavian countries (which mainly focus on the environmental side of servitization processes). Germany, on the other hand, is a historically strong manufacturing country and has been the first to embrace digital technologies in manufacturing with governmental support through the 'Industrie 4.0' national initiative. In summary, studies from Western and Northern Europe have the largest presence in the literature set analysed.

In terms of citations, the work of Ostrom et al. (2010) regarding research priorities for the science of service emerged as the most influential, with the highest number of citations (700), followed by the study, 'Service Research Priorities in a Rapidly Changing Context' (Ostrom, Patrício, Voss, Voss, & Patrı, 2015), with 388 citations, which stressed the research-priority topic of leveraging technology to advance service-exploration issues. The above studies received such a high number of citations because they demonstrate future research agendas spanning a range of topics that is much broader than digital

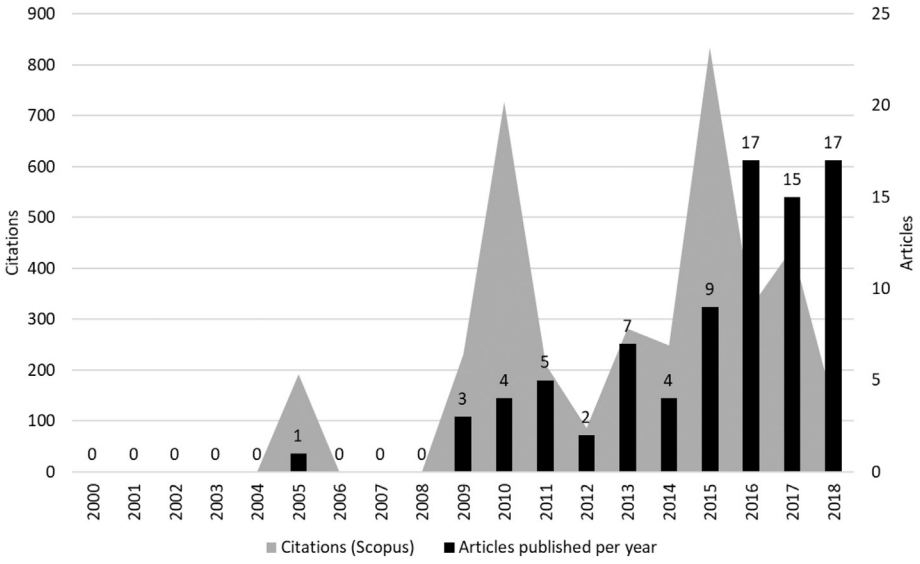

Fig. 2. Publication volume and citations in the literature up to 2018.

Table 2
Journals – impact factor – citation count.

Journal	No. articles	%	Impact Factor	Citations (Scopus)
Journal of Manufacturing Technology Management	5	5.95%	1.75	167
International Journal of Production Research	5	5.95%	2.32	139
International Journal of Advanced Manufacturing Technology	4	4.76%	2.2	154
Computers in Industry	4	4.76%	2.69	101
International Journal of Production Economics	3	3.57%	3.49	221
Sustainability	3	3.57%	2.07	25
Journal of Service Research	3	3.57%	6.84	1177
Industrial Marketing Management	3	3.57%	3.16	165
Strategic Change	3	3.57%	1.17	8
Journal of Cleaner Production	3	3.57%	5.84	21
International Journal of Operations and Production Management	2	2.38%	3.93	293
CIRP Journal of Manufacturing Science and Technology	2	2.38%	2.76	21
Communications of the Association for Information Systems	2	2.38%	1.47	51
Others	40	47.62%	–	–

Table 3
Classification based on the Scopus subject area.

Scopus subject area	No. of journals	No. of articles
Engineering	29	49
Business, Management, and Accounting	22	41
Computer Science	22	35
Decision Science	6	13
Social Sciences	6	10
Economics, Econometrics, and Finance	5	9
Energy	4	8
Environmental Science	3	7
Mathematics	3	4
Other (Chemical Engineering, Materials Science, Physics and Astronomy, Psychology)	4	4

servitization alone. For that reason, we focus on the rest of the literature set; we list, in Table 4, the ten most-cited publications after Ostrom et al. (2010) and Ostrom et al. (2015). Allmendinger and Lombreglia (2005), with 192 citations, is the most-cited article in this set. It emphasised the need for companies to provide smart services and presented four business models to embrace these services. The contribution of Brax and Jonsson (2009), cited 156 times, provides a snapshot of real life in manufacturing firms. It describes an attempt to resolve the complexities of service offerings with the support of digital technologies in creating an integrated solutions business, whereas the third paper in Table 4, Baines and Lightfoot (2014), with 137 citations, discusses how manufacturers configure their operations to deliver advanced services, focusing on the practices and technologies that underpin the capability to deliver advanced services successfully.

Based on the above information, we propose the following finding:

Finding 1. The convergence of servitization and digital technologies is recent but shows a fast-growing trend, with papers coming especially from Northern and Western Europe. Moreover, the knowledge stocks appear fragmented and distributed among different fields such as engineering, business, marketing, computer science, decision science, social science, economics, and energy and environmental science.

2.7. Methodological approaches

The papers were classified according to the methodological approach as either 'theoretical' or 'empirical'. The theoretical papers were further divided into three subcategories: a) literature reviews, b) concept development, and c) position papers. Papers in the first category present a thorough review of the studies of a given topic; those in the second category develop interpretative models about the research topics; while the articles published in the third category assume a specific position regarding the selected issue regarding how it is grounded in theory. We also used three sub-categories to further classify the empirical papers: a) qualitative, which employ empirical research methods such as case studies, focus groups, or the Delphi method; b) quantitative, which employ surveys, simulations, or other model-based analyses, and c) mixed-method papers, which combine the above-mentioned methods. As indicated in Table 5, 76.2% of the studies were classified as empirical. Qualitative empirical research is the most prevalent (49 papers, 58.3%). As expected in an emerging field (von Krogh, Rossi-Lamastra, & Haefliger, 2012)' this subset mostly relies on analyses or comparisons of qualitative cases. Among the least frequently used qualitative methods are focus groups and Delphi studies (Peters et al., 2016). Quantitative and model-driven research account for only eight articles (15.5%), with mixed-method studies recording the lowest ranking (two articles, 2.4%). Conversely, there are 20 theoretical papers, which account for around a quarter of the sample, almost equally divided among literature reviews (eight articles, 9.5%), concept development (seven articles, 8.3%), and position papers (five articles, 6%). Most of the research takes a qualitative approach, but quantitative

Table 4
Classification of the ten most-cited articles after Ostrom et al. (2010) and Ostrom et al. (2015).

Authors	Article	No. of citations
(Allmendinger & Lombreglia, 2005)	Four strategies for the age of smart services	192
(Brax & Jonsson, 2009)	Developing integrated solution offerings for remote diagnostics: A comparative case study of two manufacturers	156
(Baines & Lightfoot, 2014)	Servitization of the manufacturing firm: Exploring the operations practices and technologies that deliver advanced services	137
(Opresnik & Taisch, 2015)	The value of big data in servitization	135
(Ren et al., 2015)	Cloud manufacturing: From concept to practice	120
(Thoben et al., 2017)	'Industrie 4.0' and smart manufacturing—A review of research issues and application examples	105
(Wünderlich, Wangenheim, & Bitner, 2013)	High tech and high touch: A framework for understanding user attitudes and behaviors related to smart interactive services	89
(Meier, Völker, & Funke, 2011)	Industrial product-service systems (IPS2): Paradigm shift by mutually determined products and services	88
(Candell et al., 2009)	eMaintenance—Information logistics for maintenance support	75
(Vendrell-Herrero et al., 2017)	Servitization, digitization and supply chain interdependency	75

Table 5
Paper type and method of choice by year of publication.

Paper type	Method	Total	Percentage %
Theoretical	Literature review	8	9.5%
	Concept development	7	8.3%
	Position paper	5	6.0%
	Total	20	23.8%
Empirical	Qualitative	49	58.3%
	Quantitative	13	15.5%
	Mixed	2	2.4%
	Total	64	76.2%
	Overall total	84	100%

and conceptual studies are also represented. Case studies (single or multiple with 2–4 cases) dominate the sample. Most likely, the complexity of the topic makes it difficult to model and test relationships through survey data, so researchers prefer in-depth studies of one or a few entities. Moreover, in general, emerging fields of research are predominantly conceptual and qualitative as researchers at this phase try to establish a common vocabulary, define concepts, and explore the phenomenon.

Finding 2. The reviewed literature addresses the intersection between servitization and digital technologies, mainly through empirical, qualitative methods. In particular, the majority of the work was based on case studies, thus confirming the early stage of this research stream, wherein confirmatory and normative works are almost non-existent.

2.8. Industrial sectors

As discussed above, digital servitization has been analysed primarily through qualitative empirical studies. Fig. 3 depicts the distribution of the industry sectors addressed by the empirical studies in the reviewed literature. The machinery and industrial equipment sector was the most frequently examined, addressed in 27 studies (Ardolino et al., 2018; Baines & Lightfoot, 2014; Brax & Jonsson, 2009; Eloranta & Turunen, 2016; Geum, Lee, Kang, & Park, 2011; Grubic & Jennions, 2018; Grubic & Peppard, 2016). Miscellaneous sectors, such as the publishing industry, leather manufacturing, food retailing, and other sectors were touched on by one or two studies each, accounting for a total of 12 studies. Other relevant sectors, such as automotive and computers and IT follow, with 11 and 8 studies, respectively. Moreover, 67% of the studies concern B2B (business-to-business) industries, 23% business-to-consumer (B2C), and 10% include both B2B and B2C. We also found that most of the empirical studies address a single sector (54%) – in line with the high number of single case studies – or cases from two different sectors (23%), while broader cross-industry comparisons are infrequent. Only the survey by Belvedere, Grando, and Bielli (2013) makes some broad cross-industry comparisons among Italy-based companies, aiming at investigating the role of information and communication technologies (ICTs) in the implementation of a product-service system.

Consequently, we can posit the following finding:

Finding 3. Machinery and industrial equipment is the sector most addressed by empirical studies as it constitutes one of the most promising domains for exploring and/or exploiting the benefits of digital servitization. The automotive sector has also attracted significant attention from researchers. The rest of the literature is quite sparse around the different industrial sectors. Research tends to analyse cases from a single sector or two sectors, while broader cross-industry comparisons are almost absent.

3. Thematic analysis

The thematic analysis of the selected articles concerned four main areas. These include (1) the conceptualisation of digital servitization, (2) its benefits for customers, providers, and other stakeholders, (3) the core digital technologies adopted for servitization strategies, and (4) the linkages among specific digital technologies and different service categories.

3.1. Conceptualising 'digital servitization'

Concepts and definitions are the starting point for all research. Recent studies have shown that since both servitization and digital transformation have deep implications for business competition, it is necessary to devote more attention to their interaction (Ardolino et al., 2018; Kamp, Ochoa, & Diaz, 2017). The majority of the analysed studies relate servitization and digital transformation in a broader sense, focusing on the value creation of servitization through the application of different digital technologies, such as the Internet of Things (Zancul et al., 2016), big data (Opresnik & Taisch, 2015), analytics (Ardolino et al., 2018), and cloud computing (Wen & Zhou, 2016). Other studies focus on the business perspective on digital transformation in servitization by considering its integration with other business dimensions such as after-sales (Belvedere & Grando, 2017), production (Coreynen, Matthyssens, & Van Bockhaven, 2017), and supply chain (Vendrell-Herrero et al., 2017), while yet others address servitization as a part of Industry 4.0 (Frank, Mendes, Ayala, & Ghezzi, 2019). Table 6 presents a summary of the concepts related to digital servitization found in the scrutinised papers.

A common element across the concepts mentioned in Table 6 is a sense of the role of technology in increasing the strategic and operational effects of servitization. In analysing the papers mentioned in Table 6 and the other contributions in the literature set (Bustinza et al., 2018; Coreynen et al., 2017; Lenka et al., 2017; Opazo-Basáez et al., 2018; Opresnik & Taisch, 2015; Vendrell-Herrero et al., 2017), we found that the term *digital servitization* is associated with: 1) a change in the nature of service offerings that become digital and 'smart' (Allmendinger & Lombreglia, 2005); 2) shifts in the organisation's business models; 3) the development of new strategic assets and the

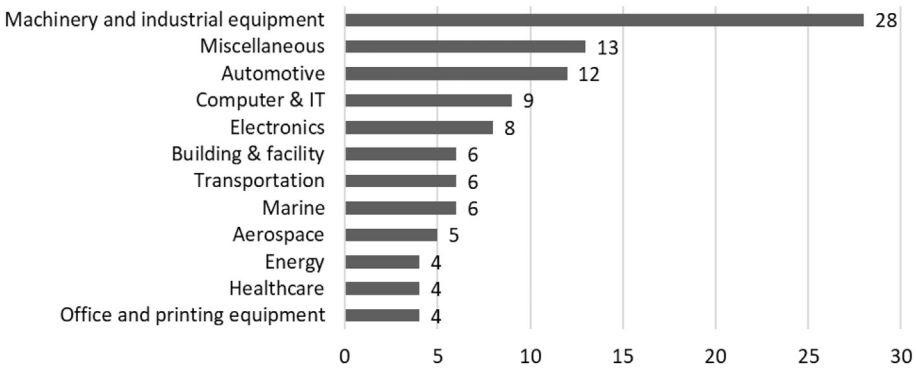

Fig. 3. Industries in which empirical studies are applied.

Table 6
Concepts of digital servitization.

Author(s)	Concepts of digital servitization
(Porter & Heppelmann, 2014)	The business model for smart solutions, which entails a combination of various products, services, software, and analytics.
(Opresnik & Taisch, 2015)	The creation and delivery of service offerings with the support of technology (big data) to increase a company's competitive advantage.
(Lenka, Parida, & Wincent, 2017)	The dematerialisation of physical goods through the support of ICT capabilities to strengthen a firms' performance and competitiveness.
(Vendrell-Herrero et al., 2017)	A reference to business models that enhance traditional non-digital goods and services with the implementation of ICT or other digital technologies.
(Kowalkowski et al., 2017)	The utilisation of digital tools for transformational processes whereby a company shifts from a product-centric to a service-centric business model and logic.
(Bustinza et al., 2018)	The need for digitally enabled integrated solutions, organisational change, and a reconfiguration of business models.
(Opazo-Basáez, Vendrell-Herrero, & Bustinza, 2018)	The adoption of digital technologies achieves more environmentally friendly production processes, communication channels, and products and services, enhancing economic value.

generation of competitive advantages, mostly due to the exploitation of data and information; and 4) the launch, monitoring, and control of initiatives aimed at achieving a more sustainable business, such as cleaner production methods. This leads us to provide the following definition of digital servitization:

Finding 4. Digital servitization can be conceptualised as the development of new services and/or the improvement of existing ones through the use of digital technologies. These can be exploited to enable new (digital) business models, to find novel ways of (co)creating value, as well as to generate knowledge from data, improve the firm's operational and environmental performance, and gain a competitive advantage.

3.2. Benefits of digital servitization

We classified the value drivers of digital servitization based on the kind of benefits they bring to the customer, the (solution) provider, the environment, and society (Krucken & Meroni, 2006). In particular, we identified which benefits can be emphasised or improved, through the adoption of digital technologies, to support the service transformation. Table 7 categorises the benefits extrapolated from the studies.

3.2.1. Benefits for customer

In terms of customer benefits, Allmendinger and Lombreglia (2005) were the first to conceptually examine how technology-based services replace onsite personal services, reduce costs, increase flexibility, improve access, and save time. Other authors investigated how digital technologies increase differentiation, flexibility, and customisation. For instance, (Wünderlich et al., 2013) developed a foundational framework for smart interactive services such as remote diagnosis and remote repair of equipment and telemedicine, stressing the benefits of increased flexibility and access. Customers are empowered when they are provided with a set of options, tools, and resources to facilitate decision-making, allowing them to tailor a product to their specific needs and desires. The above-mentioned benefits (Allmendinger & Lombreglia, 2005), which are improved by means of product and service design integration and the use of ICTs, can trigger improvements in areas such as sustainability, strategy, design, and technology (Hernández, Bhamra, & Bhamra, 2012).

3.2.2. Benefits for provider

With regard to the benefits for the provider, the application of cloud computing in manufacturing is used in innovative mechanisms to create value. This value is realised through improved customer experience, enhancement of the customer's perception of a company (and, thus, total customer lifetime value and profitability), boosting the customer's adhesion, and decreasing purchase costs (Weinman, 2016). Several authors suggest that digital servitization includes different technology-enabled, platform-based business models. These models create value by facilitating exchanges between customers and providers, by supporting firms in achieving a competitive advantage while providing customers with knowledge-based digital services during the entire product life cycle (Bustinza et al., 2018), and by leveraging network complexity (Eloranta & Turunen, 2016). For example, (Eloranta & Turunen, 2016) study a case of a technological platform that enables service delivery and fosters relationships with stakeholders. As evidenced by several researchers, digital servitization opens up new business opportunities, either for organisations to configure service-based business models to increase their competitiveness (Demirkan et al., 2015) or for new entrants (Vendrell-Herrero et al., 2017). More specifically, the study of Lerch and Gotsch (2015) found that companies harvest value and build competitive advantage by combining digital systems with PSSs. Moreover, improvements in the efficiency and effectiveness of maintenance have been considered by numerous scholars. For example, Grubic (2018) provided support for the impact of remote detection and diagnosis of problems on a reduced amount of unplanned maintenance, which leads to reductions in operating costs, delays, and cancellations as well as productivity increases.

3.2.3. Benefits for environment and society

The benefits related to the environment, such as the reduction of energy consumption and environmental impact, are also enhanced through digital servitization. Bressanelli, Adrodegari, Perona, and Saccani (2018) investigated how the IoT, big data, and analytics favour the transition towards the circular economy and how these technologies increase resource efficiency, extend product lifespan, and allow ‘closing the loop’. In addition, the continuous development of digital technologies resulted in delivering value to society. Examples are the development of low-cost and yet powerful Internet-connected devices, such as smart wearable devices that offer personalised monitoring and advice for improving fitness and well-being or smart pills that allow doctors to monitor patients' medication (Georgakopoulos & Jayaraman, 2016). Furthermore, Lindström, Hermanson, Blomstedt, and Kyösti (2018) explored how a multi-usable cloud service platform based on IoT paradigms can efficiently monitor and optimise the recycling of glass, paper, metals, and plastic by aiming at improving the knowledge of customers and consumer processes.

Finding 5. The body of literature is mostly focused on how digital technologies enable benefits traditionally related to servitization (e.g., strengthening competitiveness and reducing costs). Some studies referred quite generically to the role of digital technologies in enabling new business opportunities and revenue streams, and only a few studies indicated new, specific types of benefits, such as enabling platform-based business or empowering customers. A few studies addressed environmental benefits, indicating a relevant future area of convergence between digital servitization and the circular economy.

3.3. Digital technologies at the core of servitization strategies

Fig. 4 shows the digital technologies employed in the empirical

Table 7
Benefits of digital servitization.

Category	Benefit	References
Customer	Minimise downtime and transfer of risks to the manufacturer/provider	(Grubic, 2014) (Grubic, 2018) (Grubic, 2014, 2018)
	Secure the transmission of data	(Nybacka, Ericson, & Larsson, 2015)
	Increase differentiation, flexibility, and customisation	(Allmendinger & Lombreglia, 2005) (Wünderlich et al., 2013) (Kowalkowski et al., 2013) (Paluch & Wunderlich, 2016) (Wan, Li, Gao, Roy, & Tong, 2017)
	Improve customer performance in usage processes	(Weinman, 2016)
	Empower the customer	(Hernández et al., 2012)
Provider	Reduce service delivery costs	(Allmendinger & Lombreglia, 2005) (Zhu, Gao, Li, & Tang, 2012) (Grubic, 2018)
	Improve maintenance efficiency and effectiveness	(Rakyta, Fusco, Herčko, Závodská, & Zrnić, 2016) (Wan et al., 2017) (Grubic, 2018)
	Improve product performance and availability	(Rakyta et al., 2016) (Grubic, 2018) (Opazo-Basáez et al., 2018)
	Mitigate risks	(Grubic, 2018) (Bigdeli et al., 2018)
	Strengthen competitiveness and open up new business opportunities	(Kowalkowski et al., 2013) (Grubic, 2014) (Demirkan et al., 2015) (Lerch & Gotsch, 2015) (Vendrell-Herrero et al., 2017) (Bigdeli et al., 2018) (Bressanelli et al., 2018)
	Generate new revenue streams	(Schuh, Boos, & Völker, 2011) (Baines & Lightfoot, 2014) (Demirkan et al., 2015) (Kamp et al., 2017)
	Enable platform-based businesses	(Cenamor, Rönnberg, & Parida, 2017) (Eloranta & Turunen, 2016) (Bustinza et al., 2018) (Lindström et al., 2018)
Society and Environment	Reduce energy consumption	(Georgakopoulos & Jayaraman, 2016) (Opazo-Basáez et al., 2018)
	Reduce environmental impact	(Mourtzis, Zogopoulos, & Vlachou, 2017) (Holler et al., 2017) (Opazo-Basáez et al., 2018) (Bressanelli et al., 2018)
	Build sustainable business/production	(Hernández et al., 2012) (Opazo-Basáez et al., 2018)
	Impact on social sustainability	(Hernández et al., 2012) (Lindström et al., 2018)
	Deliver value to the surrounding society	(Georgakopoulos & Jayaraman, 2016) (Lindström et al., 2018)

studies, with reference to the list of technologies adopted by this study, which is illustrated in Table 1. A paper can be classified in more than one category when it addresses a set or a combination of technologies.

(Industrial) Internet of Things (Ardolino et al., 2018; Bigdeli et al., 2018; Cenamor et al., 2017; Demirkan et al., 2015; Holler et al., 2017; Zancul et al., 2016) is the most frequently addressed digital technology in the literature. In fact, (industrial) Internet of Things (IIoT) can be considered as a pre-condition to developing smart services since it

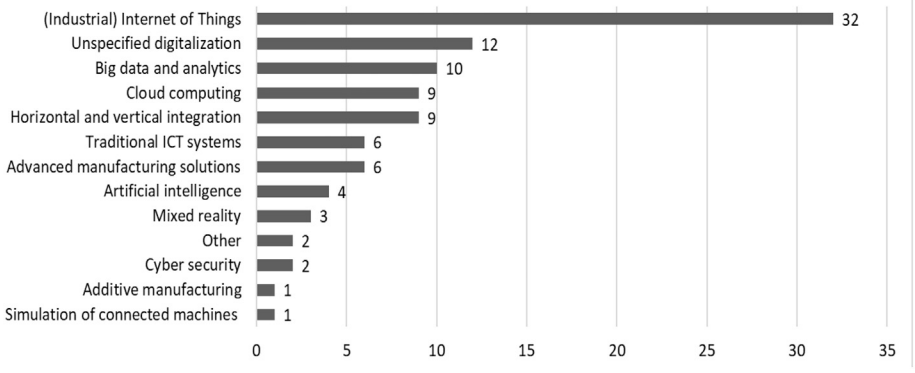

Fig. 4. Digital technologies applied in all empirical papers.

Table 8
Matching among the different digital technologies and service categories.

Technologies	Service Category			
	Base (installation, documentation, spare parts/product provision, warranty)	Intermediate (training, technical assistance, ordinary maintenance, remote monitoring, customer processes optimisation)	Advanced (customer support agreement, risk-and-reward-sharing contracts, revenue-through-use contracts)	Unspecified
(Industrial) Internet of Things	(Baines & Lightfoot, 2014; Grubic & Jennions, 2018; Grubic & Peppard, 2016; Rymaszewska et al., 2017)	(Ardolino et al., 2018; Baines & Lightfoot, 2014; Belvedere & Grando, 2017; Brax & Jonsson, 2009; Cenamor et al., 2017; Georgakopoulos & Jayaraman, 2016; Geum et al., 2011; Grubic, 2018; Grubic & Jennions, 2018; Grubic & Peppard, 2016; Holler et al., 2017; Huang, Qu, Fang, & Bramley, 2011; Lindström et al., 2018; Nybacka et al., 2015; Ren et al., 2015; Rymaszewska et al., 2017; Sakao, Öhrwall Rönnbäck, & Ölundh Sandström, 2013; Wuenderlich et al., 2015; Zancul et al., 2016)	(Ardolino et al., 2018; Baines & Lightfoot, 2014; Bigdeli et al., 2018; Brax & Jonsson, 2009; Bressanelli et al., 2018; Cenamor et al., 2017; Eloranta & Turunen, 2016; Georgakopoulos & Jayaraman, 2016; Geum et al., 2011; Grubic, 2018; Grubic & Jennions, 2018; Grubic & Peppard, 2016; Holler et al., 2017; Lim, Kim, Heo, & Kim, 2018; Wuenderlich et al., 2015; Yang, Lee, Kim, & Kwak, 2015)	(Ban et al., 2016; Demirkan et al., 2015; Jiang, Ding, & Leng, 2016; Ostrom et al., 2010, 2015; Shih, Lee, & Huarng, 2016; Valencia, Mugge, Schoormans, & Schifferstein, 2015; Wuenderlich et al., 2015)
Unspecified Digitalization	(Lenka et al., 2017; Lerch & Gotsch, 2015)	(Lenka et al., 2017; Lerch & Gotsch, 2015; Pagoropoulos, Maier, & McAloone, 2017; Paluch & Wunderlich, 2016; Sakao et al., 2013; Sakao & Lindahl, 2014)	(Baines, Lightfoot, Smart, & Fletcher, 2013; Coreynen et al., 2017; Paluch & Wunderlich, 2016; Sánchez, Marco, Basáez, Arias, & Bustinza, 2018)	(Bustinza et al., 2018; Opazo-Basáez et al., 2018; Vendrell-Herrero et al., 2017)
Big Data and Analytics	(Baines & Lightfoot, 2014)	(Ardolino et al., 2018; Baines & Lightfoot, 2014; Holler et al., 2017; Lindström et al., 2018)	(Ardolino et al., 2018; Baines & Lightfoot, 2014; Bressanelli et al., 2018; Holler et al., 2017; Lim et al., 2018)	(Demirkan et al., 2015; Jiang et al., 2016; Ostrom et al., 2015; Shih et al., 2016)
Cloud Computing		(Ardolino et al., 2018; Georgakopoulos & Jayaraman, 2016; Mourtzis et al., 2017; Ren et al., 2015; Wen & Zhou, 2016)	(Ardolino et al., 2018; Georgakopoulos & Jayaraman, 2016; Wen & Zhou, 2016)	(Demirkan et al., 2015; Jiang et al., 2016; Ostrom et al., 2010, 2015)
Horizontal and Vertical Integration	(Baines & Lightfoot, 2014)	(Baines & Lightfoot, 2014; Mourtzis et al., 2017; Ren et al., 2015; Wen & Zhou, 2016)	(Baines et al., 2011; Baines & Lightfoot, 2014; Wen & Zhou, 2016)	(Cao, Wang, Kang, & Gao, 2016; Charro & Schaefer, 2018; Roos & O'Connor, 2015; Shih et al., 2016)
Traditional ICT	(Belvedere et al., 2013; Geum et al., 2011)	(Belvedere et al., 2013; Durugbo, 2013; Geum et al., 2011; Kowalkowski et al., 2013)	(Durugbo, 2013)	(Hernández et al., 2012; Wan et al., 2017)
Advanced Manufacturing Solutions	–	(Coreynen et al., 2017; Kamp et al., 2017; Kim, Kim, You, & Park, 2009; Wiesner, Marilungo, & Thoben, 2017)	(Coreynen et al., 2017; Peters et al., 2016; Wiesner et al., 2017)	(Jiang et al., 2016)
Artificial Intelligence	–	(Holler et al., 2017; Kamp et al., 2017)	(Holler et al., 2017; Lee & Lee, 2016; Yang et al., 2015)	–
Mixed Reality	–	(Mourtzis et al., 2017)	–	(Demirkan et al., 2015; Ostrom et al., 2015)
Other	–	–	(Schmidt, Braun, Schenkl, & Mörtl, 2016; Tongur & Engwall, 2014)	–
Cyber Security	–	–	–	(Ban et al., 2016; Ostrom et al., 2010)
Additive Manufacturing	–	(Coreynen et al., 2017)	(Coreynen et al., 2017)	–
Simulation of Connected Machines	–	–	–	(Ostrom et al., 2010)

allows for the collection and transmission of data from products and systems (Ardolino et al., 2018), enabling the remote monitoring and control of such products and systems (Porter & Heppelmann, 2014). Moreover, 12 papers generically address the role of digital technologies in servitization without focusing on a specific technology (e.g., Bustinza et al., 2018; Lenka et al., 2017; Lerch & Gotsch, 2015; Vendrell-Herrero et al., 2017). Big data and analytics were addressed in 10 studies (e.g., Demirkan et al., 2015; Li, Ji, Luo, & Mi, 2016). These technologies allow the extraction of knowledge (Ardolino et al., 2018) to achieve the full potential of advanced services (Baines & Lightfoot, 2014). Specifically, through data analysis and interpretation, services based on prediction (e.g., predictive analytics), adaptive control, and optimisation of the product/system in the field can be deployed (Opresnik & Taisch, 2015). Cloud computing, the practice of using a network of remote servers to store, manage, and process data, has also received attention in the literature (nine studies). For instance, Wen and Zhou (2016) examined the cloud-based business model in manufacturing industries and proposed a way to implement servitization. Notably, the same level of attention was found for horizontal and vertical integration, which is the first step in making the Industry 4.0 vision a reality. The main idea was to propose structural changes in the organisation and management of physical projects (Charro & Schaefer, 2018) and to retain design and production capabilities to benefit the speed, effectiveness, and cost of supporting assets in advanced services contracts (Baines, Lightfoot, & Smart, 2011). Conversely, six of the analysed studies on digital technologies actually focused on the adoption of traditional ICTs (e.g., ERP and CRM systems) and an analysis of their role in servitization. Finally, cyber security, additive manufacturing, and the simulation of connected machines were discussed by fewer studies (Ban, Choi, & Kang, 2016; Kamp et al., 2017; Lee & Lee, 2016), suggesting a lower maturity level or their lower relevance as enablers of servitization processes.

In sum, most of the reviewed studies focused on the exploitation of a specific digital technology, not on their combinative effects: only IIoT has been addressed by a number of papers in combination with a second technology, generally cloud computing or big data and analytics. IIoT probably received most of the attention due to its foundational role in interconnecting supplied goods and providing smart services. There was also a significant focus on the use of big data and analytics, cloud computing, and horizontal and vertical integration. Other digital technologies that could be of interest for servitization (e.g., additive manufacturing) have not been adequately investigated yet. Finally, a number of studies deal with 'unspecified digitalization' or traditional ICTs, which did not clearly define or address the effect of specific digital technologies.

Finding 6. Among the studies, the adoption of the IIoT as a servitization enabler, the role of big data and analytics, and the role of a more generic 'digitalization' are highlighted. Limited research addresses the cumulative effect of technologies on digital servitization.

3.4. How digital technologies enable different service categories

Servitization can be adopted by companies that include services of different types in their portfolio, with very different features and implications. The analysed literature provides some insights into how digital technologies support different services types. Over the years, different classifications for the service types have been developed (Baines et al., 2009; Gaiardelli, Resta, Martinez, Pinto, & Albores, 2014). In our study, we adopted the classification into base, intermediate, and advanced services (Baines et al., 2009) due to its simplicity and because it is widely acknowledged by both scholars in the servitization domain and practitioners alike. Although it has been effectively applied to explore certain factors – such as transformation and operational technologies, skills, and capabilities – that can remarkably influence the servitization journey, it has not been used to analyse digital servitization. Base services point to product provision with a narrow range of activities and centred on and around production competences (e.g., installation, documentation, spare parts provision, product/equipment provision, and warranty). Intermediate services are based on the exploitation of production competences to assure the state and condition of equipment (e.g., training, technical assistance, ordinary and condition maintenance, remote monitoring, and customer processes optimisation). Advanced services focus on outcome assurance with extended service activities, stretching the manufacturing enterprise to take on activities that are usually internal to the customer (e.g., customer-support agreements, risk-and-reward-sharing contracts, and revenue-through-use contracts).

Table 8 presents the results of a matching exercise comparing the different digital technologies and service categories based on the empirical studies. As might be expected, IIoT has the greatest coverage in the three service categories, with big data and analytics, cloud computing, and horizontal and vertical integration coming after. Regarding the columns of Table 8, digital technologies, according to the literature, are mainly associated with the provision of either intermediate or advanced services, with less attention to base services. A potential explanation might be that these are the actual categories that allow companies to 'make the leap' towards servitized business models. However, a number of papers that remained focused at a general level did not associate digital technologies with specific types of services.

The four areas with a higher density of coverage highlight the adoption of IIoT and big data and analytics in providing mainly intermediate and advanced services. First, a significant number of scholars have investigated the adoption of IIoT by companies so as to offer intermediate services such as remote monitoring and ordinary maintenance. Remote monitoring, in particular, has attracted greater attention and is expected to become the fastest-growing technology-enabled service in the coming years (Paluch, 2016). For example, IIoT affects various product lines of Xerox Corporation, and these technology-embedded products provide the interfaces for services such as document management, handling, archiving, or imaging (Geum et al., 2011). Grubic and Peppard (2016) also examined how this technology is used in practice to support the service-oriented value propositions of manufacturers and identify the key factors involved in successfully executing this strategy. Grubic (2018), having studied four manufacturing companies operating in different sectors, notes that remote monitoring benefits consumers and service providers but warns about the challenge of creating value through this service. Second, many researchers have investigated the role of IIoT in offering advanced services such as risk-and-reward-sharing contracts and revenue-through-use contracts, etc. (Cenamor et al., 2017), have also investigated how the adoption of a platform approach leverages the implementation of advanced service offerings as performance- or outcomes-based contracts (e.g., risk and reward sharing) in manufacturing firms. Another example of advanced services that are supported by IIoT is the contract offering that gives customers the right to access and use a laundry washing service under a pay-per-month or pay-per-use scheme (Bressanelli et al., 2018). Moreover, the usage of big data and analytics is associated with the provision of intermediate and advanced services. The study of Lindström et al. (2018) analysed a multi-usable service platform for big data collection and analytics, which focused on monitoring and optimising the recycling process. In relation to advanced services, Ardolino et al. (2018) discussed how Kone used analytics to develop condition-monitoring and predictive maintenance services that minimise downtime and speed up equipment restoration. Holler et al. (2017) emphasised the use of data analytics in combination with machine intelligence to provide predictive maintenance, while Ardolino et al. (2018) discussed how Canon, through the development of a cloud platform, managed to overcome security issues in automatic data collection and invoicing, and the Internet connection of printers.

Finding 7. The studies in the literature focus, in particular, on the role of digital technologies – especially IIoT, big data and analytics, cloud computing, and horizontal and vertical integration – in supporting the development of intermediate and advanced services such as

Table 9
Main research gaps emerging from this paper's findings and related future research directions.

Related finding	Research gap	Future research direction
#1	Literature on digital servitization comes mainly from mature economies, particularly in Western and Northern Europe.	1. Address how digital servitization influences competitive, environmental, and societal aspects in emerging economies.
#2	Most of the studies are empirical, based on one or a few case studies. Confirmatory and normative works are almost absent.	2A. Carry out prescriptive research to support decision-making. 2B. Carry out confirmatory research to test conceptual developments (e.g., relationships between digital technologies and benefits achieved; prerequisites for digital servitization).
#3	Empirical research on digital servitization had a predominant focus on the Machinery & Equipment industry and single sector studies.	3A. Extend empirical research to other sectors, especially in B2C industries. 3B. Adopt a broader perspective aimed at comparing different companies and sectors, moving from an anecdotal to a more comprehensive approach, e.g., through surveys.
#4	Several themes have been associated with the digital servitization concept (e.g., 'smartness', new business models, value co-creation, knowledge development, and sustainability, performance improvement); however, a fragmented view on them prevails.	4. Adopt a systemic and holistic approach to the themes associated with digital servitization
#5	New specific types of benefits of servitization compared to traditionally acknowledged ones have been associated with digital servitization, with little detail on how they can be achieved.	5. Investigate the mechanisms through which digital servitization leads to distinct benefits, such as data monetisation, platform businesses, and circular economy.
#6	Only a few digital technologies have been analysed in relation to servitization (predominantly IIoT), and, most often, in isolation.	6A. Extend the research focus to under-investigated digital technologies. 6B. Address the combinative effect of given stacks of digital technologies.
#7	Digital technologies (especially IIoT) have been analysed in relation to the development of new forms of agreements or revenue models related to asset operation and asset life management.	7. Address the evolution of how digital technologies enable advancing towards further stages of the service business or completely new forms of business.

remote monitoring, predictive maintenance, customer support agreements, and performance-based contracts. Following this line of reasoning, we can assume that digitalization could favour the shift towards the frontier – or simply a more sophisticated extent – of the service business.

4. Discussion and research agenda

This study, which has reviewed the literature on digital servitization, represents the first attempt to consolidate relevant research on this topic of apparent growing interest. The analysis showed that a hitherto limited number of studies have addressed the convergence between research on digital technologies and servitization. In the following, based on the seven findings that summarise the descriptive and thematic analyses carried out, we identify gaps and future research directions. They are summarised in Table 9.

4.1. Addressing developing economies

Unsurprisingly, as illustrated by *Finding #1,* the digital servitization phenomenon has been investigated mostly in countries that are leaders in research on servitization or product service systems (e.g., the UK and Scandinavia), pure services (the US), or countries where the phenomenon of digitalization of manufacturing, or 'Industry 4.0', was initially developed (Germany in particular). They are all mature economies, and their growing interest in digital servitization reflects the view that servitization of manufacturing is seen as an attractive strategy for differentiating and generating new competitive advantages in mature markets (Coreynen et al., 2017). On the other hand, the disruptive potential of digital technologies and the way digital transformation changes competitive scenarios (for instance, by allowing start-ups to compete with major industry incumbents) have been emphasised (Zancul et al., 2016). This latter aspect suggests that a relevant area for research is instead related to the role of digital servitization in developing economies. In fact, the adoption of digital technologies can accelerate the shift from products to services and the adoption of new business models. This form of leapfrogging enabled by technologies (Steinmuller, 2001) may entail important transformations to both B2B and B2C industries in low-income countries where, for instance, the move from traditional ownership to sharing or pay-x-use services could open massive markets for products. Expected impacts relate to increasing societal well-being, enhancing the competitiveness of the involved firms and networks, and, at the same time, allowing for more sustainable forms of development (Gouvea, Kapelianis, & Kassicieh, 2018).

4.2. Models and frameworks that support decision-making

As pointed out in *Finding #2,* most research has revolved around case studies in order to understand how digital technologies operate in servitization processes in specific companies, with the aim of hypothesising general patterns. We believe that it is crucial to define how the adoption of digital servitization changes companies' operations and processes in practice (Belvedere et al., 2013; Ostrom et al., 2015), and there is still space for more interpretative research. Additional descriptive models (assessment or maturity models) for practitioners can be developed to position companies on the path towards digital servitization.

Besides that, prescriptive research aimed at supporting the decision-making process when companies address digital servitization is required, in line with a broader call for normative servitization research (Baines et al., 2017). Specifically, more attention needs to be paid to the integration of digital technologies into the design process so as to advance service offerings. At the same time, managers would need decision support mechanisms when mapping their new strategy and designing technology innovation projects that are consistent with business model innovation or service portfolio expansion plans. This would lead to the definition of normative models aimed at pointing out the development paths of digital servitization, with greater potential for companies in relation to internal and external contingency factors (e.g., sector, company size, and supply chain position). In particular, such models would allow the identification not only of the more relevant options for the evolution of product-service offerings based on digital technologies but also of success factors to be pursued and obstacles to be overcome.

Confirmatory research to test the conceptual models and hypotheses developed in case study research is also required to support such processes, for instance, to verify quantitatively on a broader sample the organisational (e.g., capabilities, roles, and tools) or market prerequisites for successfully undertaking a digital servitization process.

4.3. Industrial sectors

From *Finding #3*, we learned that empirical research on digital servitization has focused on a limited number of industrial sectors, with predominant attention focused on that of machinery and industrial equipment. Moreover, more than half the studies focus on just one sector (often based on a single case), while a few consider two or more sectors, generally based on individual cases. To enhance generalisability, more sectors with more significant numbers of companies should be analysed in empirical studies (with the possible adoption of the survey method as well): in particular, B2C industries have received scant attention to date. Moreover, for both generalisation and appreciation of the (possible) differences related to the development of digital servitization in different industries, cross-industrial studies are called for.

4.4. Conceptualising 'digital servitization'

Finding #4 highlights how several themes are encompassed by the concept of digital servitization in the literature. They are, in particular, the development of 'smart' or digital services, the move to new business models, value co-creation with customers, knowledge development, the sustainability of product-services, and performance improvement for the company and customers. These themes have been harmonised in the original list of definitions related to digital servitization proposed in Section 4.1. Given the sparseness of the research on the topic in the literature and the absence of a common definition of the phenomenon, the extant research tends to focus on one or a few of the themes only. Although a detailed investigation of the single concepts can increase the knowledge of digital servitization, we suggest that research should adopt a holistic and interconnected approach to the digital servitization phenomenon. In particular, future research should analyse how the identified characteristics of digital servitization are mutually developed and reinforced or, conversely, mutually hinder each other.

4.5. Benefits of digital servitization

Our study identified some of the benefits of digital servitization (see *Finding #5*). A number of these benefits have been traditionally associated with servitization, such as the minimisation of downtime for the customer (Baines & Lightfoot, 2013), the transfer of risk to the manufacturer (Neely, 2008), and revenue and profit increases through new revenue streams (Wise & Baumgartner, 1999). In these cases, digital technologies are a way to achieve the benefits more effectively, to a greater extent, or at a lower cost.

However, other types of benefits associated with digital servitization open up new opportunities or move traditionally acknowledged benefits to a different level. For instance, digital servitization may entail the development of entirely new businesses based on the exploitation of data (Opresnik & Taisch, 2015) or platform business models, connecting products and customers thanks to IIoT and cloud technologies (Cenamor et al., 2017), or customer empowerment through augmented and virtual reality (Mourtzis et al., 2017). Also, digital technologies spanning from IIoT to 3D printing amplify the potential for environmental and societal improvements of product service systems, enabling the circular economy paradigm (Bressanelli et al., 2018). Additional research is required to better characterise the benefits of digital servitization in these categories, understand how the implementation of specific technologies, services, and or organisational practices allow their achievement, and analyse the specific obstacles to be faced.

4.6. Digital technologies at the core of servitization strategies

Finding #6 highlights that only a few digital technologies have been extensively analysed in relation to servitization (predominantly IIoT, followed at a distance by big data, cloud computing, and horizontal and vertical integration) and, most often, in isolation. Immediate opportunities for future work are rooted in the need to explore the role of each digital technology within servitization. With respect to the adoption of some technology stacks, there is still significant work to be done. To exemplify, the relevance of cyber security to servitization has been neglected, despite trust and privacy being considered major obstacles to the diffusion of servitized and data-driven business models. Therefore, additional work is needed to explore how cyber security can be successfully applied to offer performance-based contracts (Georgakopoulos & Jayaraman, 2016). In addition, the blockchain, a technology not explicitly addressed in the literature analysis since it has not, to the best of our knowledge, been investigated at all in the digital servitization literature, presents a relevant exploitation potential in the servitization realm that deserves to be addressed by future research studies. Another example concerns additive manufacturing. This technology could couple decentralised service operational models with the reduction of inventories and environmental benefits; however, scant research to date has dealt with this technology in a servitization context. Another issue emerging from our review concerns the joint role of technologies in the development of new services and servitization strategies: research to date has tended to focus mainly on one technology or on digital technologies as an indistinct whole. It would be very helpful to study how individual digital technologies could interact and help in achieving thorough digital servitization and the related benefits, as carried out in research by Ardolino et al. (2018) for IIoT, cloud computing, and big data analytics.

4.7. How digital technologies enable different service categories

From *Finding #7*, we learn that digital technologies (especially IIoT) have been analysed in relation to the development of more advanced services and, consequently, new forms of agreements or revenue models especially related to asset operations and asset life management. Thus, we suggest investigating how digital technologies can make a difference in the shift or transition to further stages of the service business. An interesting area of investigation would be to revisit how business models are designed in specific customer-service provider relationships and how they have evolved over time through the introduction of IoT (Rymaszewska et al., 2017) or other technologies. This future research area is connected to the investigation of the benefits that can be achieved through digital servitization by moving to completely new types of businesses or business models, such as platforms (see *Finding* and *Future research direction #5*).

5. Conclusion

Digital servitization based on 'smart connected products' carries the potential to revolutionise the manufacturing industry (Porter & Heppelmann, 2014). Despite the popularity of this transformation among practitioners, research on the topic is still in a nascent stage and fragmented across a wide number of disciplines and outlets, and it remains mainly based on anecdotal evidence based on single case studies rather than on a coherent set of explanatory theories and prescriptive models. This study has analysed the research on digital servitization from the perspective of different fields to describe the current state of the art and suggests a research agenda for the future.

By synthesizing the current conceptual and empirical literature, this review provides an understanding of the phenomenon of digital servitization. Since the research directed towards how companies actually form such a transformation strategy is scarce, one contribution of this paper stands as the harmonisation of the existing knowledge, thereby conceptualising and providing greater insight into the main characteristics of digital servitization. In particular, we summarise the results of the descriptive and thematic analysis around seven findings that point out 1) the research distribution in terms of time, geography, and publication outlets, 2) the methodological approaches adopted, 3) the

industrial sectors touched by empirical applications, 4) the characteristics of digital servitization (in particular, we propose an original definition of *digital servitization*), 5) the benefits that can be achieved, 6) the specific technologies addressed, and 7) their links with base, intermediate, and advanced services.

These findings also made it possible to identify certain gaps in the literature on digital servitization that led to the final conceptual contribution of the paper: the identification of seven directions for future research.

In addition, our paper also has practical implications. As in the case of all literature reviews, ours is helpful for time-conscious managers who do not have the time to track down all the available literature themselves. In particular, practitioners can find in this paper a summary of the state of the research on digital servitization and may find particularly useful the section addressing how digital technologies enable different service categories when considering digital servitization implementation in their own company (Section 4.4). In addition, the summary of the benefits for customers, providers, and other stakeholders should be of interest (Section 4.2). It is our hope that the scholarly literature will provide even better managerial advice as the field matures.

It must also be noted that the literature review conducted in this paper has some limitations. First, we focused on academic journal papers written in English. We are aware that excluding papers in other languages as well as other types of publications, such as conference papers, might have circumscribed our findings. Second, due to the keyword-based search method applied to the publications, it is possible that some papers that are related to the research focus but contain different keywords were excluded. Finally, the findings of a literature review greatly depend on the reviewers' experience and educational background.

Appendix A. Classification of Industry 4.0 frameworks based on digital technologies

Author	Digital technologies									
	Industrial internet of things	Big data and analytics	Cloud computing	Cyber security	Mixed reality	Advanced manufacturing solutions	Additive manufacturing	Simulation of connected machines	Horizontal and vertical system integration	Artificial intelligence
(Astrid et al., 2017)	X	X	X	X	X	X	X	X	X	
(Bortolini et al., 2017)	X	X	X		X	X		X		X
(Lu, 2017)	X	X	X		X					
(Santos et al., 2017)	X		X			X	X			X
(Celaschi, 2017)	X	X	X		X	X	X			
(Guoping et al., 2017)	X	X	X				X	X		X
(Caruso, 2017)	X					X	X		X	X
(Hofmann & Rüsch, 2017)	X					X				
(Pereira & Romero, 2-017)	X	X	X		X	X				
(Wan et al., 2017)	X	X	X			X	X			
(Pfeiffer, 2017)	X	X			X	X	X			
(Sung, 2017)	X	X	X			X				
(Thoben et al., 2017)	X	X				X				
(Tjahjono, 2017)	X	X	X		X	X	X			X
(Suri et al., 2017)	X									
(Ferreira et al., 2017)	X	X	X			X				
(Liao et al., 2017)	X	X				X			X	
(Petrasch & Hentschke, 2016)	X		X							
(Hastbacka, Jantunen-y, Karailaz, & Barna, 2016)	X		X							
Industrie 4.0	X	X	X	X	X	X	X	X		
Intelligent Factory Cluster	X	X	X	X	X	X	X	X	X	
Industrie du Futur	X	X		X	X	X	X	X		X
High Value Manufacturing Catapult	X	X	X	X		X	X			
Industria Conectada 4.0	X	X	X		X	X	X			X

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