The Digital Servitization of Manufacturing Sector: Evidence from a Worldwide Digital Servitization Survey

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Abstract. To boost revenues and create a lasting competitive advantage in the present global market, an increasing number of manufacturing companies are experimenting with shifting from product-centric offerings to service solutions leveraging digital technologies according to the Industry 4.0 paradigm. This (digital) transformation, known as "Digital Servitization", aims to provide new (digital) services and/or enhance existing ones. Yet, this transformation is challenging and manufacturing companies frequently have trouble meeting their expectations. To shed light on the current state of the Digital Servitization trend in the global manufacturing sector, researchers involved in the ASAP Service Management Forum and the IFIP WG5.7 Special Interest Group on "Service Systems Design, Engineering and Management" have conducted an international survey targeting manufacturing SME managers. The main survey objectives are twofold: (i) to analyse how manufacturing companies are implementing digital technologies to support their Digital Servitization transformation from traditional business models based on product sales to models focused on service delivery, and (ii) to identify which

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critical issues and best practices are characterizing the Digital Servitization transformation of manufacturing companies. Survey results have demonstrated a rising trend in the global manufacturing sector towards the use of digital technologies for service delivery, but more mature servitization strategies, data management activities, coordination efforts at the ecosystem level, and supporting tools for conscious decisions in the delivery of (digital) services are still required to succeed in the new Digital Servitization arena.

Keywords: Digital Servitization · Survey · Industry 4.0 · Product-Service System

1 Introduction

Servitization and *Digitalization* are two important research trends that are profoundly changing (manufacturing) businesses [1, 2]. Although these have different origins, the two areas of research recently converged because of their mutual interdependences to provide a higher source of differentiation, and therefore competitiveness, on the global market. *Industry 4.0 technologies* have led manufacturing companies to find new configurations of product-service offerings, thus favouring their "servitization journey" [3]. The *servitization journey* that manufacturing companies are following in their attempt to innovate their business models and value offerings through the benefits derived from the (manufacturing) Servitization and Industry 4.0 paradigms is known as "Digital Servitization" [4].

Even though manufacturing companies are still product-centric and their revenues are mainly generated by the sales of new products, an increasing trend is highlighted towards offering *product-service solutions* [5]. Industry 4.0 technologies, such as the Industrial Internet of Things (IIoT), Cyber Security, and Cloud Computing can contribute to the spreading of *servitized business models* like "XaaS (Everything-as-a-Service)". Also, a high interest emerged in more complex Industry 4.0 technologies namely Mixed Reality, and Artificial Intelligence (AI) or Machine Learning (ML) [5].

Although the scientific and grey literature generally agrees that the development of advanced digital/smart technologies has and is encouraging the adoption of innovative "services" by manufacturing companies, the embracing and deployment of *Digital Servitization strategies* is not thoroughly documented in the literature [6]. There is no evidence of how manufacturing companies are changing their operational, tactical, and strategic processes to leverage the adoption of advanced digital/smart technologies inside their service and/or product-service offerings. Multiple authors exploring the *Digital Servitization trend* (and its journey) have focused on identifying its challenges and barriers like the lack of human capabilities, ecosystem network, and organizational guidelines as well as on its opportunities namely the increase in revenues and the diversification value offerings on the market [7–10]. However, the same authors suggest the need for (more) "quantitative evidence" to better support and back up the mentioned benefits of embarking on a *Digital Servitization transformation.*

In light of these considerations, this paper provides a thorough overview of the current state of the global manufacturing sector's journey towards *Digital Servitization,* starting

with the degrees of *Servitization* and *Digitalization* (a.k.a. digital technology adoption) among manufacturing companies, and moving on to the actions that are needed to enable successful *Digital Servitization transformations,* according to five main research areas, as highlighted by [6]: (i) Strategies and new business models for the Digital Servitization transformations, which include companies' technical and organizational change; (ii) Innovative Product-Service Systems (PSSs) design methods and tools with an emphasis on the digital component of PSSs; (iii) Tools for assessing PSSs design and predicting PSSs performances; (iv) Methods, tools, and technologies for collecting and managing PSSs knowledge along their lifecycle; and (v) Sustainable PSS business models enhanced by digital/smart technologies.

This last investigation will be fundamental to capture the challenges, barriers, and opportunities manufacturing companies are dealing with nowadays when aiming for a *Digital Servitization transformation.* To conduct this study, the authors developed a survey target for manufacturing companies worldwide, and the collected answers were deployed to provide an overview of the *Digital Servitization trend/journey.*

The paper is structured as follows: Sect. 2 presents the research methodology used in this survey study; Sect. 3 shows the survey results obtained from the analysis of the collected responses; Sect. 4 discusses the main evidence related to the Digital Servitization journey in the manufacturing context; and, finally, Sect. 5 concludes this work.

2 Research Methodology

This paper uses an *exploratory survey approach* to understand the current state of the *Digital Servitization trend* worldwide. The questionnaire was developed by a group of 15 international experts in the fields of servitization and product-service systems, manufacturing engineering and operations, and Industry 4.0, mainly from Europe and the Americas, who defined the survey structure based on the Industry 4.0 and Product-Service Systems (PSSs) literature analysis. As a result, the survey is structured in two parts – as presented in Fig. 1. The first (obligatory) section is concerned with the manufacturing companies' service and/or product-service offerings and primary characteristics; while the second (optional) section is devoted to the manufacturing companies already engaged in a *Digital Servitization transformation effort* by looking at their level of adoption of Industry 4.0 technologies in their services delivery and, especially, at the actions these companies are taking to comply with their *Digital Servitization transformation expectations.*

Once developed, the survey was validated by the involved researchers and then disseminated among a global network of manufacturing companies by e-mail and social media posts. The preliminary results, after six months of collection, were presented in [5]. Meanwhile, the survey continued to collect responses reaching 314 responses in total from January 2022 to January 2023. Recalling that the survey included two sections, only 165 respondents completed also the second part of the questionnaire (53% of the total sample).

The following section provides a detailed description of the current state of the *Digital Servitization trend* in the global manufacturing sector as a result of the analysis of the collected responses.

Part 1		
D1-D5	**Respondent information** (position, business function, professional experience time)	
D6-D12	**Company characteristics** (name, industry, number of employees, gross annual turnover, market, revenue streams and business trends)	
D13	**Industry 4.0 perspective**	**Opportunities** coming from digital technologies in the factory floor and for the creation of new products.
D14	**(Digital) Service offering**	**Services** in the portfolio of companies and whether they are offered and delivered through **digital solutions**.
D15		Understand the use of digital technologies to improve existing services, develop new services, and offer more integrated product-service solutions.

Part 2		
D17	**Digital technologies**	Level of adoption of the Industry 4.0 technologies, as detailed by Paschou et al. (2020), in the service delivery.
D18-D20	**(Digital) Servitization Journey**	Actions businesses take to comply with their Digital Servitization transformation process at the strategic, tactical, and operational levels divided in 5 subjects (Pirola et al., 2020): • Digital Servitization • PSS design • Assessing tools for PSS decisions • Knowledge management along the lifecycle • Sustainable business models

Fig. 1. Sections of the Survey

3 Survey Results

3.1 Descriptive Analysis of the Sample

The respondents are mainly directors, managers, and staff with 20 years of experience on average and with very heterogeneous business functions: General Management (23%), Service/After Sales (21%), Sales (12%), IT (11%), R&D/Engineering (11%), Production & Quality (10%), Marketing (7%), Supply Chain (3%), and other (2%).

As referenced by the *Global Industry Classification Standard* [11], the respondent (manufacturing) companies belong mainly to the industrial sector (i.e., capital goods and transportation), followed by the consumer non-durable goods (i.e., food, beverage, tobacco, household products) and consumer durable goods (i.e., consumer electronics and home appliances) sector(s), and then the information technology & communication services sector (see Table 1).

Considering the size of the companies, the sample is equally balanced, however large enterprises account for a greater share. Tables 1 and 2 summarize the composition of the sample by looking, respectively, at the industrial sector and the company size. Moreover, half of the sample (52% of the respondent companies) is located in Western Europe, followed by East Europe (38%), and then the Americas (11%).

165 respondents declared that they have adopted Industry 4.0 technologies in their service delivery, which corresponds to 53% of the total sample. These (manufacturing) companies were investigated in depth in the second part of the survey guiding the authors to point out the challenges, barriers, and opportunities that exist in a *Digital Servitization transformation.* Furthermore, the smallest sample is characterized by a higher percentage of large enterprises (47%), followed by medium (27%) and small-sized (26%) enterprises (SMEs), and it is mainly composed of (manufacturing) companies belonging to the Industrial, IT & Communication Services, and Consumer Goods (Non-Durable and Durables) sectors, respectively 56%, 16%, and 15%.

Table 1. Classification of the Respondents based on Companies' Industry Sectors (GICS)

Industry Sector	N° of Respondents
Industrial	145 (46%)
Consumer Goods (Non-Durable and Durables)	69 (22%)
Information Technology & Communication Services	42 (13%)
Materials	33 (11%)
Financials & Real Estate	10 (3%)
Health Care	9 (3%)
Utilities	6 (2%)

Table 2. Classification of the Respondents based on Companies' Size

Company's Size	N° of Respondents
Large Enterprise (more than 250 employees)	127 (40%)
Medium Enterprise (between 250 – 50 employees)	93 (30%)
Small Enterprise (less than 50 employees)	93 (30%)

3.2 Service Offerings: Current State

The first important evidence collected from this empirical study is related to the presence of a diversified *service portfolio* among companies (see Fig. 2).

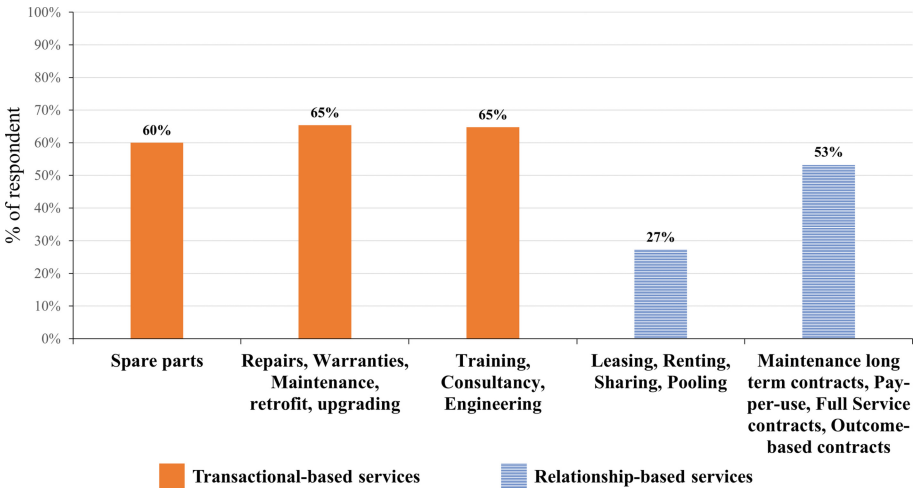

Fig. 2. Current Service Provision of the Responding Companies

It was determined that training, consulting, and engineering; repairs, warranties, maintenance, retrofit, and upgrading; and spare parts are the most in-demand being offered by 60–65% of the respondent companies. These service offerings are mainly *product-oriented* and *transactional-based* according to the nature of the interaction between the customer [12]. This is aligned with the literature that shows a higher application of *transactional services* but a higher interest in more *advanced services* in the manufacturing sector. In turn, 53% of respondents declared to also include *relationship-based services* in their offerings. Examples are long-term maintenance contracts, pay-per-use, full-service contracts, and outcome-based contracts. These services are based on *relationship-based interactions* between the provider and the customer. Also leasing, renting, pooling, and sharing are characterized by a *relationship interaction* with the customer which can vary ranging from short- to long-term contracts, but they are still not widely spread (27%).

Additionally, estimates of the prevalence of services among the (manufacturing) companies' portfolios revealed that large enterprises have a wider range of services than SMEs (see Fig. 3).

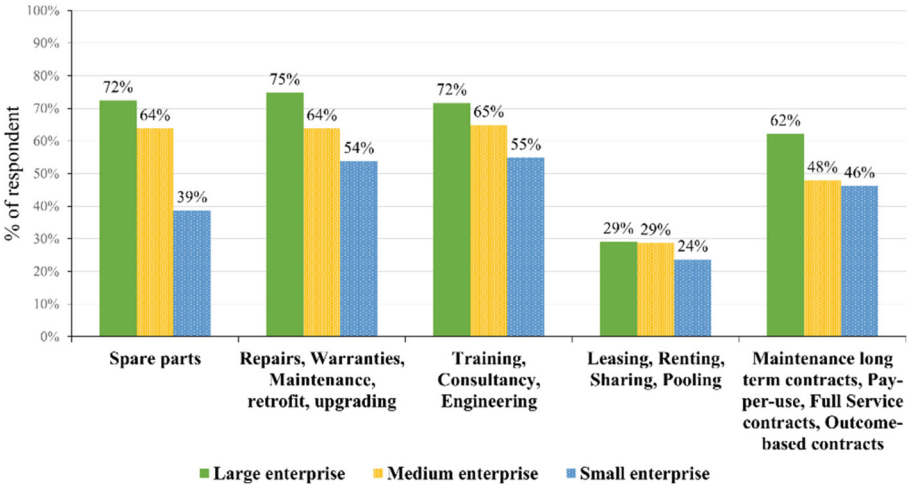

Fig. 3. Current Service Provision of the Responding Companies divided by Company Size

Especially by looking at long-term maintenance contracts, pay-per-use, full-service contracts, and outcome-based contracts, it is evident the difference between large enterprises and SMEs which may be linked to the difficulty in structuring these types of services. The *service portfolio* of small enterprises is more limited in terms of both service quantity and type. Small enterprises differ significantly, particularly in the provision of spare parts, which may be related to the lesser portion of companies belonging to the industrial sector inside this cluster.

Notwithstanding the evidence from the *service portfolios,* it was found that a very small number of businesses had made services their primary business. Indeed, data collected on the revenue stream generated by new product sales still confirm that, nowadays, companies are still "product-centric", as shown in Fig. 4.

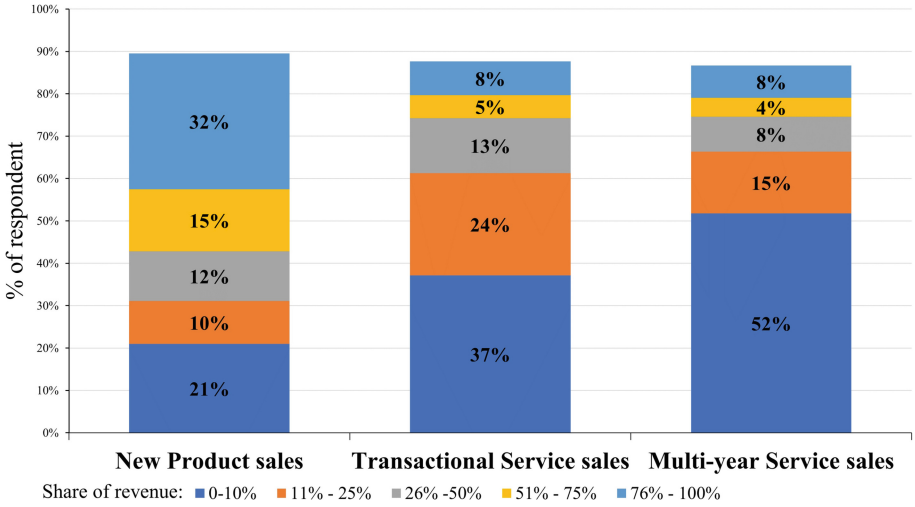

Fig. 4. Actual Revenue Generation of the Responding Companies

The companies that generate at least 25% of their total revenues from *transactional services sales* are around 26% of the sample; this value is reduced to 20% when looking at the *multi-year service sales.* Among them, it was observed that small enterprises are the best performing in economic terms as they can monetize from both "transactional" and "multi-year service" more than medium and large enterprises (see Fig. 5).

Specifically, 34% of the respondents among small enterprises generate at least 25% of the total revenues from *transactional service sales,* while among large and medium enterprises, this percentage does not exceed 25%. This difference is even more evident when looking at *multi-year services,* where 31% of small enterprises generate at least 25% of the total revenues while only 16% of large and 15% of medium enterprises can generate that revenue share. This finding is especially significant since the previous analysis shows that small businesses have a restricted range of service options, and it might inspire more research in the future.

3.3 Industry 4.0 Technologies for Service Delivery: Current State and Future Trends

Hereafter, the results collected in the second part of the survey are presented. It is worth mentioning that 53% of the respondents have completed the second part of the questionnaire declaring that they have adopted Industry 4.0 technologies in their service offerings. In particular, by looking at the detailed Industry 4.0 technologies adopted

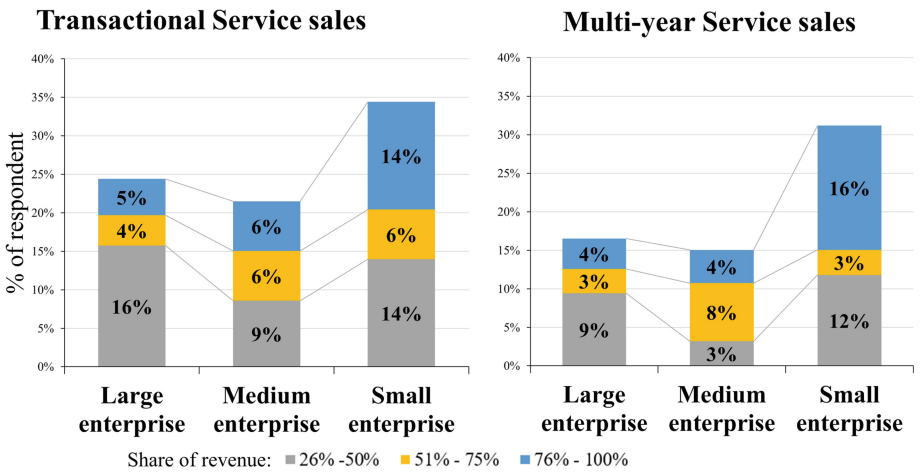

Fig. 5. Actual Generation of Almost 25% of the Total Revenues from the Service Sales (Transactional & Multi-year Services) of the Responding Companies divided by Company Size

[13], the (Industrial) Internet of Things (IIoT), Cloud Computing, and Cyber Security appear to be the most widely used and established for service delivery. While Artificial Intelligence (AI)/Machine Learning (ML), Mixed Reality, Big Data Analytics (BDA), and Simulation have the most potential for adoption (see Table 3). Small enterprises, representing 26% of this new sample, have been seen to delay the adoption of digital/smart technologies since they appear to be in the "first wave" of digitalization and are largely investing in the three most widely used ones (i.e., IoT, Cloud Computing, and Cyber Security). While large enterprises (47% of the sample) are now shifting their interest towards more complex digital/smart technologies, having already in place the above-mentioned ones as reported in Fig. 6.

Table 3. Current State of Adoption of Industry 4.0 Technologies for Service Delivery

Industry 4.0 Technology (as defined by Paschou et al. 2021)	Already Adopted (%)	Evaluating Adoption (%)
(Industrial) Internet of Things	50	33
Cloud Computing	47	32
Cyber Security	43	30
Big Data Analytics	35	43
Simulation of Connected Machines	24	42
Mixed Reality (Virtual and Augmented Reality)	23	44
Artificial Intelligence/Machine Learning	20	49
Advanced Manufacturing Solutions	13	31
Additive Manufacturing/3D-printing	13	27

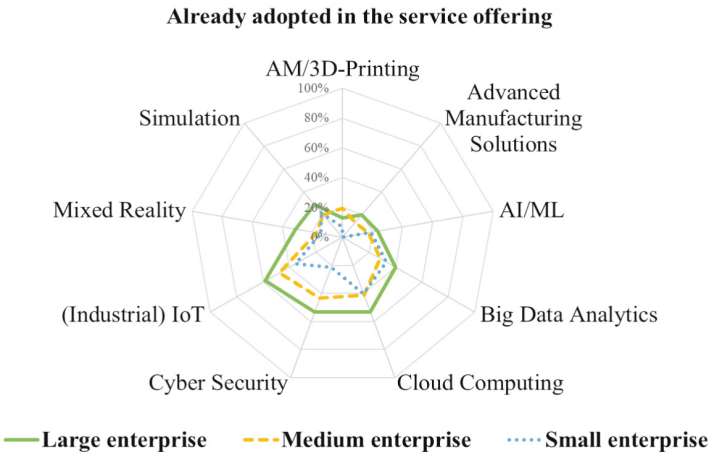

Fig. 6. Industry 4.0 Technologies Current State of Adoption for Service Delivery divided by Company Size: (a) Already Adopted, and (b) Evaluating Adoption

3.4 Digital Servitization Research Trends

The second part of the questionnaire is focused on investigating the process of "Digitalization of Services" by analysing the strengths and weaknesses highlighted in the literature. Different actions and practices derived from the five main research areas identified by [6]: (i) Digital Servitization strategies and business models, (ii) Innovative PSSs design methods and tools, (iii) Tools for assessing PSSs designs and performances, (iv) Methods, tools, and technologies for PSSs knowledge management along their lifecycle, and (v) Technology-enhanced Sustainable PSS business models – were studied by asking the respondents to provide their personal perceptions based on the Linkert

scale (i.e., *strongly disagree*, *disagree*, *agree*, *strongly agree,* and *N/A*). In the following subsections, the authors reported the descriptive obtained results.

Digital Servitization Strategies and Business Models

(Manufacturing) companies have pointed out that they are investing in *digital services* because they perceive their added values (e.g., increasing revenues, facing competition on the market, and answer to customer requests), but to date, the revenues originated by digital services do not exceed the ones generated by traditional services sales. The companies which have defined a *Digital Servitization strategy* are 60% of the second part sample, and the ones succeeding in communicating the value of advanced digital services are still 57%. It follows that almost half of the sample, even when offering a *digital service solution,* does so without a strategy in place or being aware that it is not effectively communicating the added value of "digital services". When viewed from the perspective of the ecosystem, most of the companies do not consider a "co-opetition strategy"; instead, they focus primarily on developing partnerships with IT providers since most of them do not have internal competencies yet. Furthermore, companies rely on external expertise for building knowledge of digital service offerings but also new internal competencies are being developed. Figure 7 shows the above-mentioned results neglecting the not answered and not-applicable responses to make the visualization easier to be understood.

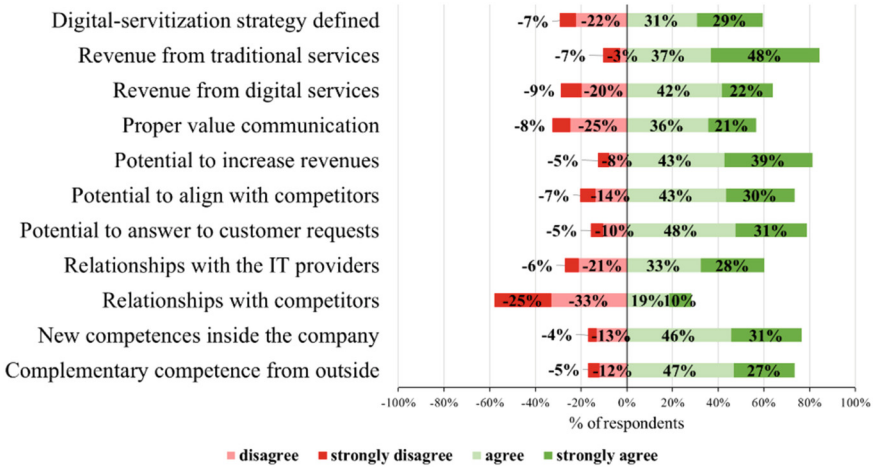

Fig. 7. Respondent Perceptions on the Actions related to a Digital Servitization Strategy

Innovative PSSs' Design Methods and Tools

Industry 4.0 technologies enable the collection of product operational data, in particular IoT systems, but only more than half (58% on average) of the responding companies exploit this data to design services (e.g., the threshold for maintenance). The main source for developing services still remains "customer feedback" obtained through reports, claims, social, etc. (77%). Simulation is not actually utilized for supporting the design

of new services. 64% of the companies had a designated budget that may have an impact on their technical advancement. Results are reported in Fig. 8.

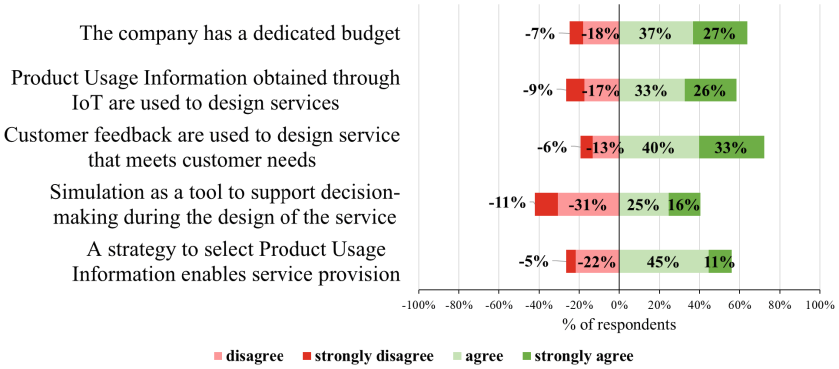

Fig. 8. Respondent Perceptions on Actions related to PSSs Design Methods and Tools

Tools for Assessing PSSs' Designs and Performances

The assessment of PSSs' designs and performances is one of the least addressed research areas in the scientific literature [6]. By examining the responses (see Fig. 9), it appears that most of the businesses have implemented systems and metrics to evaluate services economically and financially and to assess the performances of their service delivery processes. Nevertheless, from a risk and environmental standpoint, businesses do not have the necessary resources to assess risks and their effects on the environment.

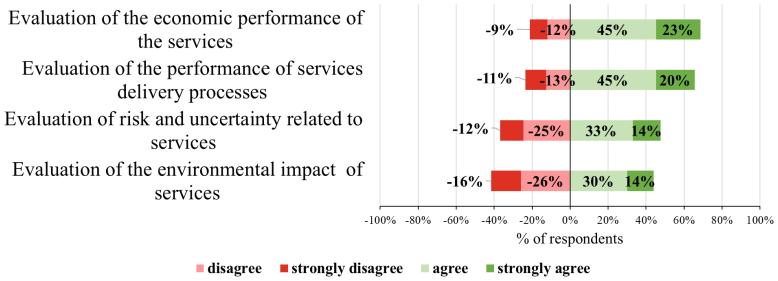

Fig. 9. Respondent Perceptions on the Assessment of PSSs Designs & Performances

PSSs' Knowledge Management Along Their Lifecycle

PSSs literature suggests that advanced (Industry 4.0) technologies are expected to support knowledge discovery, knowledge sharing, and collaboration along the PSS lifecycle by allowing the extraction of data from products (e.g., using IoT systems), the analysis of this data to understand the significant knowledge in it (e.g., using BDA, ML, AI), and its real-time sharing (e.g., Cloud Computing) for better decision-making. This topic was

also addressed in the survey, but the obtained results show that nowadays IoT-based product usage data does not appear to support the delivery of services, and ML and AI are not widely used to extract information/knowledge from products and services, enhance their design, or support digital services (see Fig. 10). The PSSs literature also suggests that one of the main challenges in data management is the "data property issue" [8]. However, companies that have already undertaken a *Digital Servitization transformation* have managed this issue. Only 21% of businesses do not currently have agreements with their clients on the flow of data, and this number drops even further (to just 13%) when one takes into account the agreements on data property and privacy.

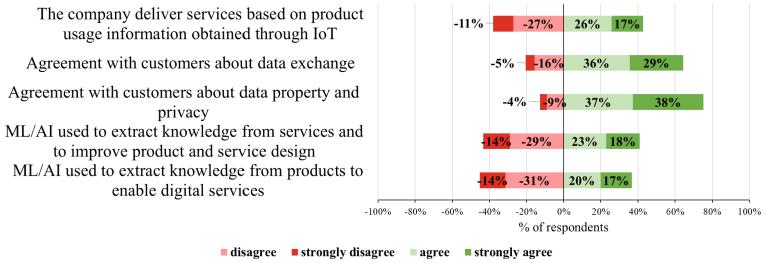

Fig. 10. Respondent Perceptions on PSSs Knowledge Management along their Lifecycle

Technology-Enhanced Sustainable PSS Business Models

Digital services are perceived as a tool to enable sustainability initiatives (see Fig. 11). In particular, services such as "reconfigurability" and "upgradability" of products are seen as key strategies to achieve sustainable solutions. This is probably due to the possibility of extending the product lifecycle thus reducing the resource consumption of the manufacturing of new products. Despite this, the survey has highlighted the absence of metrics to use for the environmental sustainability assessment. This aspect, therefore, needs to be further investigated.

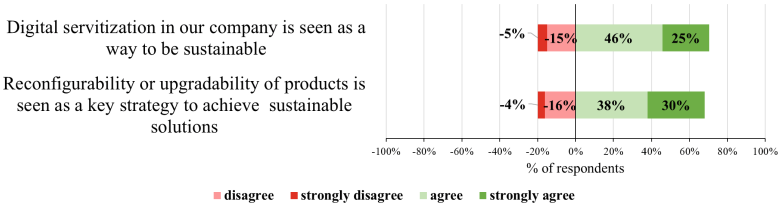

Fig. 11. Respondent Perceptions on Technology-enhanced Sustainable PSS Business Models

4 Discussion

The survey data analysis has determined the current state of the global manufacturing sector when looking at its adoption of the *Digital Servitization trend* for service delivery. Nowadays, the global manufacturing sector is still dominated by product-centric

companies coming from the traditional manufacturing industries. Consequently, the main source of revenue for these companies is the sales of new products. However, although limited, some (manufacturing) companies have made "services" their main business. Especially *transactional-based services,* which are the ones that have strong dependencies on the product (e.g., spare parts, maintenance, training, etc.), and are the most adopted in the service portfolios. Also, a significant number of companies present *relationship-based services,* mainly in the form of multi-year service contracts. However, it came to the attention that companies are not monetizing very well on services, especially large enterprises, even though they present a highly diversified service offerings portfolio. The adoption of Industry 4.0 technologies appears to contribute to a more diversified service offerings portfolio. It is possible to state that IoT systems, Cloud Computing, and Cyber Security are the Industry 4.0 technologies leading the "first wave" of digitalization, but an increasing interest is demonstrated by large enterprises towards AI/ML, Mixed Reality, and Big Data Analytics. However, from the collected data, it is not possible to correlate the diversification of the service portfolio with revenue generation. Moreover, examining the association between the digital service opportunities and the specific technologies within Industry 4.0 would be interesting as future research for identifying which digital services could be offered for each technology of set of technologies adopted.

Other important contributions of the paper are linked to the challenges, barriers, and opportunities of "Digital Servitization" (Table 4). Hence, quantitative evidence is obtained by the analysis of the survey data.

The introduction of digital/smart technologies in services poses multiple challenges to companies that can be overcome if a *Digital Servitization strategy* is in place. However, most (manufacturing) companies responding to the survey are not driven by a strategy and therefore fail to communicate the value of the "digital services" they offer and, consequently, to monetize from their sales. The development of competencies is recognized as a key feature for implementing digital services, and the majority of respondent companies already have developed new competencies inside the company itself or from external, thus overcoming this important challenge. Furthermore, the survey highlighted that there is scarce integration at the ecosystem level, so broadening the service perspective to the entire ecosystem is one of the challenges of the coming years. Digital/Smart technologies allow for extracting, sharing, and analysing data about product information and customer preferences. These data can be utilized to design new advanced services or improve existing ones, but how to extract useful information and then utilize this data are still a huge challenge. Indeed, despite IoT being the most adopted Industry 4.0 technology to deliver services, there is currently little use of product information in service design or delivery. The design of advanced services should then be supported, but the survey highlighted the lack of supporting tools. In addition, companies do not use metrics related to risk and environmental performances that can support the evaluation and selection of service offerings. Therefore, from an operational perspective, decision support is needed for engineering advanced services that could effectively enhance value and increase environmental sustainability.

On the other hand, the study has pointed out multiple opportunities generated by a *Digital Servitization transformation.* It enhances revenues, allows for differentiation

from competitors, and for strengthening the relationships with the customers. Data property and privacy issues seem to be resolved by companies allowing for data sharing, which is an important opportunity for resolving data management issues and ecosystem communication. However, it was already noticed that the challenges related to this are still very relevant. A higher percentage of companies provide economic and service delivery process performance metrics to measure service impacts, and this evidence is not surprising. The majority of the examples proposed by the literature regarding PSSs performance evaluation look at the economic viewpoint. But the interesting findings here are related to "environmental sustainability". The survey highlights that an important opportunity of *Digital Servitization* is the possibility of complying with sustainable goals. However, only a few of the respondents have metrics for assessing the environmental bottom-line dimension of the triple bottom line, making these companies an interesting sample for further research.

In light of these considerations, it could be interesting to understand if the factors perceived as "barriers" have some correlations between them and the highlighted opportunities, for example, understand how digital capabilities affect the highlighted opportunities coming from the adoption of digital services as discussed by [14]. It will also be interesting to determine whether the aforementioned opportunities and obstacles are viewed similarly across the various organizational dimensions. Therefore, statistical analysis will be performed as future developments for the study.

Table 4. Challenges/Barriers & Opportunities of Digital Servitization Transformation

Research Areas	Challenges/Barriers	Opportunities
Digital Servitization Strategies and Business Models	• Difficulty in value communication • Ecosystem network development with competitors and IT providers	• Increase in revenues • Customer loyalty through services • Differentiation from competitors
Innovative PSSs' Design Methods and Tools	• Difficulty in designing services from product usage information • Lack of supporting tools for service design	
Tools for Assessing PSSs' Designs and Performances	• Lack of metrics for risk assessment of services • Lack of metrics for environmental assessment of services	• Evaluation of the economic and service delivery performances
PSSs' Knowledge Management along their Lifecycle	• Difficulty in extracting knowledge from product and service	• Data sharing with the customer
Technology-enhanced Sustainable PSS Business Models		• Sustainability achievement

5 Conclusions

A survey study has been conducted to provide a current state of the *Digital Servitization trend* in the global manufacturing sector. The exploratory survey succeeded in shedding light on the actual service offerings of businesses which, although revealed to be product-centric, have diversified service offerings (e.g., transactional-based services and service contracts) in their portfolio. The adoption of Industry 4.0 technologies in the service offering is still in the preliminary phase since companies are not adopting the more advanced/complex digital/smart technologies up to now. This could be explained by the fact that the transition from a "servitization approach" to a "digital servitization approach" is an articulated, complex, and non-linear one that necessitates strategic, tactical, and operational knowledge, and support for impacting business performances. A focused strategy, cooperation with the customer as well as with all the other players in the ecosystem, data management efforts, and supporting tools for conscious decisions in the design of service delivery processes were identified as the main challenges of the current industrial landscape from the quantitative analysis of the collected responses, representing the starting point where to focus on in the next years for succeeding in the *Digital Servitization arena.*

The exploration of the five main research areas on "Digital Servitization" was limited to the industrial domain, but it would be worthwhile to emphasize the findings in the literature. The setting of the exploration is another constraint worth addressing. Indeed, most of the survey results were gathered in Europe, notably from the industrial businesses network established by the universities and research institutions engaged in the survey distribution.

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