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Digital servitization business typologies in the manufacturing sector

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ABSTRACT

Manufacturing companies undergo a transformative journey in digital servitization, necessitating strategic, tactical, and operational shifts. The existing literature outlines the best practices on this process and examines challenges and opportunities through qualitative empirical evidence. We enrich the investigation through a quantitative explanatory research approach, employing a survey targeting manufacturing companies from multiple countries. Analyzing the responses using cluster analysis, we found three business typologies with specific behaviors related to digital servitization: digital experimentalists, strategic pioneers, and digital servitization novices. This research contributes valuable insights into the varied behaviors adopted by manufacturing firms in navigating the digital servitization landscape.

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1. Introduction

Servitization is a transformation process that has characterized the manufacturing context for decades. This term was first coined in the late 1980s by Vandermerwe and Rada in 1988 [1], referring to how companies provide services along with or instead of their traditional physical products in integrated Product–Service Systems (PSS) [2]. This transformation has significantly affected the industrial landscape, prompting many companies to redefine their corporate strategies and how they interact with their customers [3].

The advent of Industry 4.0 has further influenced the servitization trend positively through the advantages that digital technologies bring, leading researchers to investigate this new transformation process, referred to as digital servitization [4]. Nowadays, the penetration of digital technologies into the manufacturing context is well documented and, as a result, the servitization phenomenon is usually explored considering the digitalization process.

The digital servitization literature has surged in recent years, with many studies analyzing the phenomenon from various perspectives. These contributions have shed light on the actions and best practices required to implement transformation processes for digital servitization [5], [6], [7], [8], [9] while highlighting the main challenges [10], [11], [12], [13], [14], [15], [16], and opportunities on the firm performance related to its implementation [17], [18], [19], [20], [21], [22], [23]. Despite, these do not delve into the understanding of the approaches that the companies are experimenting with in their digital servitization implementation.

Although the scientific and grey literature agrees on the mutual benefits of digital technologies and innovative services, the adoption and deployment of digital servitization strategies are mainly documented through conceptual and qualitative empirical studies [5], [6], [10], [15], [16], [24], [25], [26], [27], [28]. Despite the valuable contributions of such studies in defining best practices and the challenges and opportunities of digital servitization, conceptual and qualitative research has mainly conducted in-depth case studies on different topics, such as small- and medium-sized enterprises (SMEs) (e.g., in Le-Dain [15] and Rapaccini [27] studies) or specific industries (e.g., in Galvani and Bocconcelli [8] and González Chávez [14] studies). These studies provide detailed narratives and comprehensive analyses uncovering underlying mechanisms, cultural factors, and organizational dynamics by exploring complex phenomena and interactions within companies.

However, the digital servitization phenomenon also needs to be investigated from a broad perspective to identify general patterns, trends, and correlations that might not be visible through the in-depth, focused lens of case studies. Triangulating the knowledge from case studies in the literature with data collected through surveys in the same area can support a new understanding of manufacturing firms' current digital servitization processes. A broader perspective allows for generalization of phenomena and prior findings but also for a comparison of cross-business realities. Firms may behave differently when embracing digital servitization but ultimately deliver similar outcomes. This was suggested by Chen [6], who described that neither the move to service nor the use of digital technologies came first in digital servitization transformation because of the presence of a strong interplay between business model change and the use of digital technology throughout the entire process. In the study mentioned, the authors still argued on equifinality, which is defined as the presence of different behaviours among manufacturing companies that lead to the same digital servitization outcomes.

Therefore, we aim to empirically investigate the digital servitization process of manufacturing firms using a quantitative research method. The goal is to understand the diverse approaches companies adopt to offer digital services, as well as to analyze the different perspectives and strategic decisions driving these approaches. By analyzing the business characteristics of these companies approaching the digital servitization transformation, common patterns are also investigated to understand trends and business typologies characterizing the digital servitization process. The following are the research questions that guide this study:

RQ: How do manufacturing firms approach the implementation of digital servitization, and what common patterns characterize this transformation process?

The remainder of this article is structured as follows. First, the literature on servitization and digital servitization is provided in Section 2. The research design and methods are then described in Section 3, showing the phases characterizing the research approach adopted. The analysis identifies three different business typologies based on actions related to digital servitization. The collected responses and each business typology are described in detail in Section 4 and then discussed in Section 5. Finally, the article concludes with theoretical and practical implications, as well as the limitations of the study and areas of future research, in Section 6.

2. Literature review

The emergence and growth of the servitization phenomenon in the manufacturing sector over the last few decades represent a transformative shift from traditional product-centric value offerings and to service-oriented business models. This trend has intensified even more over the last decade due to evolving market dynamics and customer preferences [29]; this has led manufacturers to increasingly recognize the value of offering comprehensive solutions and outcomes rather than just selling physical products. This paradigm shift has proven to enhance customer satisfaction and foster long-term relationships as customers' needs evolve together with the value offerings of manufacturers beyond the initial sale. Consequently, this transformation drives innovation and creates sustainable revenue streams through ongoing service engagements [29], [30].

From a service innovation perspective, the transition to digital servitization strategies signifies a further evolution in the manufacturing landscape as industries embrace advanced digital technologies to enhance their service-oriented offerings. Although the term "digital servitization" is not new in academic and industrial contexts, existing research has primarily focused on its opportunities for firm performance and the challenges it presents, often through conceptual or qualitative studies. However, there is a notable gap in the literature regarding the maturity of manufacturing firms undergoing digital servitization and the diverse approaches they adopt in this transformation process [31], [32], [33]. Specifically, the field lacks a systematic investigation of how manufacturing companies implement digital servitization across different contexts and fields. This study aims to address these gaps by providing a comprehensive analysis of the digital servitization process adopted by the companies. The goal is to explore the diverse approaches adopted by firms and identify common patterns and business typologies characterizing this transformation.

The findings from the digital servitization literature overview [34] conducted using the Scopus database are presented in the following sections.

2.1 Opportunities brought by digital servitization

In the present day, servitization and digitalization function collaboratively. They both have a beneficial impact on each other. Martin-Pena [18] showed a positive correlation between the level of servitization and digitalization; by improving digitalization, servitization indirectly boosts profit by decreasing expenses, enhancing efficiency, delivering integrated packages, and building customer interactions. The benefits and opportunities of digital servitization have been widely explored in the literature. Qualitative studies have examined its potential for business growth, competitive advantage, and value creation [11], [15], [16], as well as environmental and social benefits [16], [35]. Other authors have further substantiated the positive impacts of digitalization and servitization on firms' economic performance (e.g., profitability and productivity) through empirical quantitative studies (i.e., surveys) [19], [20], [21], [22], [23]. However, they are mainly country-specific studies (Spanish [18], Swedish [19], British [23], or Serbian companies [20], [21]). Despite these valuable contributions, there is still limited understanding of the diverse approaches companies adopt to implement digital servitization. Existing research has not sufficiently explored the strategies and processes firms use to integrate digital technologies into their service offerings.

2.2 Challenges of digital servitization

Several studies have focused their attention on identifying the main challenges experienced by manufacturing companies in the development of their transformation processes [8], [11], [12], [13], [14], [15], [26]. Among these challenges are difficulties in managing data and the fear of data sharing, a lack of human and digital capabilities, the absence of an ecosystem network and organizational and strategic guidelines, the consequent difficulties in designing and choosing new product/service business models, high investment costs and the resulting financial risks, and cultural resistance. These insights emerged by exploring the literature, resulting in a predominantly conceptual understanding derived from the analysis of the industrial context through case studies and offering empirical evidence that remains largely qualitative and often challenging to generalize [28].

2.3 Best practices of digital servitization

Most of the aforementioned challenges appear to be the key elements for successfully integrating the digitalization of services. To provide a comprehensive overview of digital servitization actions at the strategic, tactical, and operational levels, Pirola [35], highlighted five areas of interest when dealing with digital servitization: (i) strategies and new business model elements; (ii) innovative PSS design methods and tools with an emphasis on the digital component; (iii) assessment tools for supporting PSS decisions and predicting performance; (iv) methods, tools, and technologies for collecting and managing PSS knowledge along the life cycle; and (v) sustainable PSS business models enhanced by Industry 4.0 technologies.

In the first area (i.e., strategies and new business model elements) the definition of a clear digital servitization strategy is suggested as a core best practice, as also confirmed by other theoretical studies [7], [31], [32], but also the development or enhancement of technological capabilities, and soft skills, such as negotiation and collaboration skills at the managerial, marketing, and sales levels [9], [10], [25]. A key practice highlighted across multiple studies is the creation of an ecosystem that involves stakeholders like customers and technological partners [5], [6], [7], [9], [10], [25], [27], [35] which is particularly relevant for smaller manufacturers [27], [33].

In the second one (i.e., PSS design methods and tools) existing methods or new ones are studied to design data-driven PSS enabled and optimized using product usage information obtained through Internet of Things (IoT) systems [35], [36]. This, together with the use of Machine Learning (ML) and Artificial Intelligence (AI), are found to be important elements for better understanding and integrating customer needs in the design phase [16]. Tools such as simulations and digital twins are also being investigated, though real-world applications, especially for digital twins, remain limited [37].

In the third area of assessment tools for supporting PSS decisions and predicting performance, the literature shows the potential of simulation and lifecycle data exploitation for supporting more conscious strategic decisions, like towards sustainable development goals and proposals of sustainable PSS considering the impacts on sustainability aspects [38], [39], [40], [41], and supporting service operations, like maintenance services [42].

In the fourth area (i.e., knowledge management along the life cycle) centralization of decisions and integration play crucial roles, and properly collecting, managing, and sharing life cycle data required for digital platforms and customer interfaces managing the knowledge raised by the data is a delicate but fundamental requirement for digital transformation success [5], [25].

Finally, the fifth highlights the role of digital services and smart PSS business models as enablers of circular economy principles and sustainability goals [41], [43], [44]. Even though the literature still argues about the real sustainability impacts of PSS [45], among others, the possibility of upgrading and reconfiguring products is seen as beneficial for sustainability purposes [46].

Research agendas continue to recommend these areas of study, emphasizing the necessity of additional research into the phenomenon of digital servitization [47].

However, most of the existing literature is conceptual and qualitative, often based on case studies and limited data collection. Consequently, a quantitative approach, like the one proposed in this paper, has the potential to provide a broader, more generalized perspective, complementing the existing findings from conceptual and case study research and explaining the diverse approaches that manufacturing companies are experimenting with in their digital servitization processes [12], [15], [16], [26].

3. Methodology

This study used a quantitative explanatory approach [48]. The following describes each phase. In the data sampling phase, we first set the study's boundaries to manufacturing firms that offer services to their customers, are interested in the digitalization of their services, and primarily operate in the capital goods and consumer industrial sectors without any restrictions on the geographical area. The data were collected from the participating companies constituting the sample (primary data) through an online survey. The development of the survey, its structure and main measures are reported in Section 3.1, and its administration to the targeted companies is reported in Section 3.2. Given the specificities of the target, we used a convenience sample [49] for this purpose by delivering the survey to those manufacturing companies in contact with the research centers involved in the study. Once the data was collected, the responses were checked for validity and completeness and then analyzed. A description of the collected responses was generated to characterize the sample for analysis. Cluster analysis was selected among statistical techniques because of its ability to determine the natural groupings of observations that have common characteristics or behave in similar ways [50]. This technique enabled the definition of groups of manufacturing firms that showed similar characteristics related to digital servitization actions. Specific survey responses targeted at the actions and best practices characterizing digital servitization research were utilized to investigate the current business typologies and related approaches toward digital servitization. A detailed description of the cluster analysis is provided in Section 3.3. The survey method for data collection and subsequent cluster analysis for the data analysis in the manufacturing field are suggested by the literature [51], [52], [53]. Finally, the results obtained were discussed and interpreted. The research framework for the survey study is shown in Figure 1.

3.1 Questionnaire development and measures

The questionnaire was meticulously designed by a group of 15 international academic experts in the fields of servitization and PSS, mainly from Europe and the Americas. The purpose was to gain comprehensive insights into the service offerings and actions employed by companies during their digital servitization journeys, as informed by the prevailing research trends outlined in the scientific and gray literature. Consequently, the questionnaire was structured into two distinct sections, as depicted in Figure 2. The first part, which was compulsory for all participants, was designed to collect information about the service and/or product–service offerings of the manufacturing companies, as well as their primary characteristics. The optional second part targets manufacturing companies that are already engaged in digital servitization transformation.

For the purpose of this analysis, the digital servitization transformation process (Part 2, section B of Figure 2) was used to cluster business typologies. These typologies serve as the main distinguishing elements of the level of digital servitization within manufacturing companies. The remaining part of the questionnaire was used to characterize the business typologies, specifically the company characteristics, such as sectors and size, their service offering portfolio, the digital technologies used in the service offerings, and the revenue streams derived from the services. Each of these measures is described in detail in the following subsections.

After the questionnaire was developed, it underwent a validation process supervised by the researchers, who were actively involved in the study. The

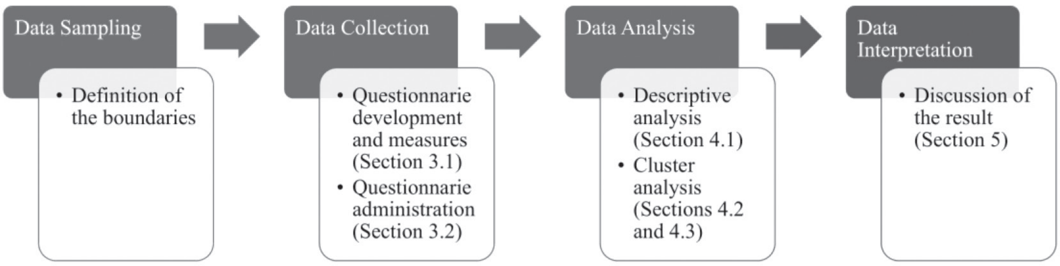

Figure 1. Research framework based on Gelo [48]

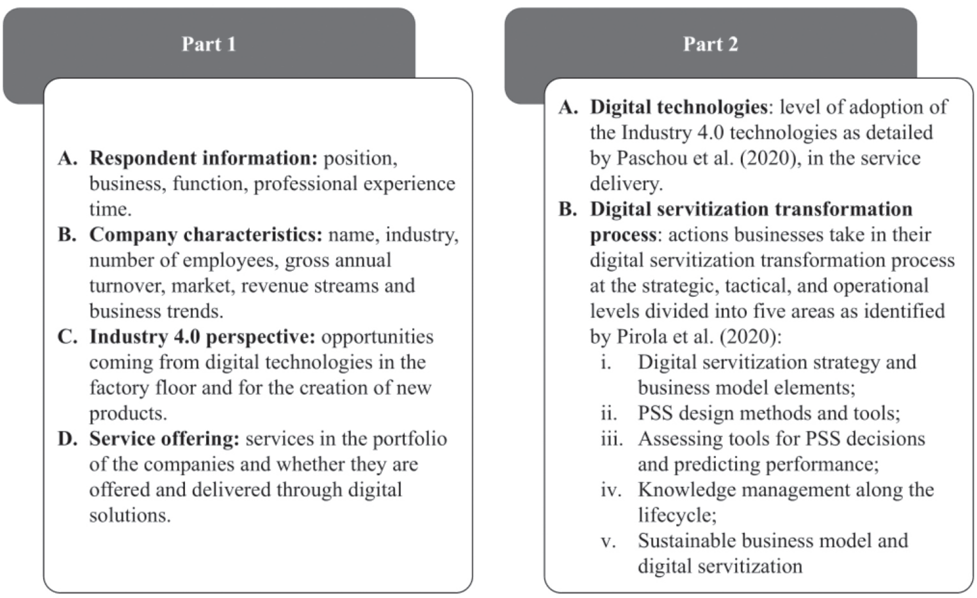

Figure 2. The questionnaire's structure

researcher carried out this validation procedure to ensure that the questionnaire accurately, consistently, and pertinently captured the crucial information required to address the research question (content validity). Additionally, a small sample of businesses was asked to evaluate the usability and comprehensibility of the questionnaire before it was formally distributed online. Finally, it was translated into Italian, Dutch, Spanish, Swedish, and Serbian.

3.1.1 Digital servitization transformation process

The questionnaire included the digital servitization actions at the strategic, tactical, and operational levels undertaken by the companies during these transformation processes, as reported in Part 2, section B of Figure 2, to capture the strengths and challenges of each business typology. These actions are derived from the literature analysis described before (best practices) and are divided into the five research areas identified by Pirola [35]. The resulting questions from Q0 to Q27 are reported in *Appendix A*. To investigate how the companies have undertaken specific actions in these areas, the respondents were asked to rate their degree of agreement based on a forced Likert scale (where 1 = strongly disagree to 4 = strongly agree), as it has the potential to guide people to make definite choices [54].

3.1.2 Service offering

Respondents indicated on a list of core services as suggested by Gaiardelli [55], which services their company offered, constituting Part 1, section D of the questionnaire's structure (Figure 2). The list encompasses product-related and transactional-based services, including spare parts (SO1), repairs, warranties, maintenance, retrofit, upgrading (SO2), and training, consultancy, and engineering services (SO3). The list also includes relationship-based services that demand close and continuous client relationships, such as leasing, renting, sharing, and pooling (SO4) (also known as usage-oriented services), and long-term maintenance contracts, pay-per-use, full-service contracts, and outcome-based contracts (SO5), which are characterized by a longer-term perspective.

3.1.3 Digital technologies

The exploration of digital technology adoption was done through closed-ended questions (yes or no) in Part 2, section A of Figure 2. The list of digital technologies was retrieved from an existing analysis of the digital servitization literature [16]. These technologies include industrial IoT systems (IIoT) which represent the most frequently addressed by the literature, big data analytics which allows for predictive services and optimization of products and services through data analysis and interpretation; cloud computing, which serves for cloud-based business models; advanced manufacturing solutions; ML and AI; mixed realities, such as virtual reality and augmented reality; cyber security; additive manufacturing (AM); and simulation of connected machines.

3.1.4 Other characterization variables

The other variables used in the analysis to characterize the business typologies are the sector of activities, identified from the list provided by the Global Industry Classification Standard (GICS) classification and the size of the company, measured in terms of number of employees and gross profit, and the revenue generation from the service offering, representing Part 1, section B of the questionnaire (Figure 2). To capture the revenue streams from the service offerings, respondents were asked to indicate the proportion of revenue generated by two main categories of services over the company's total revenue: one with a transactional nature and the other with a relationship nature of interaction with the customer. The revenue generation was classified into three levels: lower share (0-10% and 11-25%), medium share (26-50%, 51-75%), and high share (76-100%) to reflect how companies derive revenue from service.

3.2 Questionnaire administration

The online questionnaire was distributed to a network of manufacturing companies that were most accessible to the researchers. This network comprised contacts from various professional associations, industry groups, and previous research collaborations. The distribution was conducted via e-mail and social media posts, exploiting both the researchers' direct channels and extended networks via research centers and trade associations. The participants could respond to the online questionnaire by clicking the URL provided in the message.

The survey was conducted from January 2022 to January 2023, allowing ample time for the participants to respond. A total of 314 responses were received. Most of these responses were from within the European Union, reflecting the researchers' primary networks and indicating accessibility. An exclusion criterion was identified to answer the research question; only those respondents who were interested and engaged in digital servitization, which was explored in the second part of the survey, were included in the final dataset. Only complete responses, including the second (facultative) part of the survey, were considered valid. After the exclusion criterion was applied, a total of 102 responses were considered valid and met the required sample profile. These valid responses provided comprehensive insights into digital servitization processes, ensuring the relevance and quality of the data.

3.3 Cluster analysis

Cluster analysis is a statistical technique used to determine the natural groupings of observations. It involves classifying or segmenting entities into homogeneous groups with common characteristics or that behave similarly [50]. Among the various clustering techniques, the K-means algorithm was selected for this analysis due to its efficiency and speed, making it ideal for handling large datasets with multiple variables, as in this study [56]. As previously mentioned, the variables used for clusterization referred to the actions and best practices characterizing the digital servitization transformation processes in five research areas [35]. For what concerns the N/A values and missing values, they were replaced by the mean of the responses in the same column variable. This technique artificially minimizes data variability, which might result in potential bias in parameter estimations [57]. The cluster analysis was performed for solutions ranging from three to 10 clusters. These solutions were then compared based on the Calinski and Harabasz pseudo-F index [58] in which large values indicate distinct clustering. The results led to the selection of a tree-cluster solution; the p-values were tested using ANOVA to show significant differences between the three clusters.

Cluster profiles were determined in two ways. The first was by examining the mean values of responses to the cluster analysis questions, which provided insights into how the companies are managing the digital servitization process and the actions they have or have not taken. The second was by analyzing the characterization variables that recall the service offering portfolio, its revenue stream, the digital level and the company's primary characteristics which complement and enrich previous results. The findings obtained are described in Section 4.

4. Results

The 102 responses collected underwent a preliminary analysis to understand the main characteristics of the final sample. The respondents and the companies' information, mainly from the first part of the questionnaire, are reported in Section 4.1. The cluster analysis was then performed, as mentioned in Section 3.3. This analysis led to the identification of three separate clusters as optimal solutions that highlighted the presence of three different behaviors when it comes to exploring the digital servitization journey of manufacturing companies. In the following section, the clusters' main characteristics are presented to clearly describe the current state of digital servitization in the manufacturing industry.

4.1 Descriptive analysis

The sample collected consisted of 102 responses, described in terms of respondent characteristics (e.g., position and business function) and company information (e.g., sectors, dimensions based on the number of employees and gross annual turnover, and geographical area). Table 1 and Table 2 describe the results.

Table 1. Respondents' characteristics (Source: the authors)

Respondents' characteristics	Percentage %
Position	
Manager	38%
Director	32%
Staff	21%
Other	9%
Business Function	
Services/After-sales	30%
General Management	21%
R&D/Engineering	14%
IT	6%
Sales	5%
Marketing	3%
Production and Quality	3%
Supply Chain	3%
Other	15%

Most of the respondents were managers and directors who had an average of 20 years of experience and held positions of responsibility and authority; they oversaw various aspects of their organizations, such as decision-making, strategy implementation,

Table 2. Companies' information (Source: the authors)

Business Characteristics	Percentage %
Sector	
Capital Goods (Aerospace and Defense, Construction, Machinery, Medical, Electronics)	78%
Consumer (Durable) Goods (Consumer Electronics, Domestic Appliances)	10%
Consumer (Non-Durable) Goods (Food, Beverage, Tobacco, Household Products)	5%
Oil and Gas, Energy, Chemicals and Materials (Plastics, Metals, Mining, Paper)	5%
Pharma, Biotech, and Life Sciences	2%
Dimension	
Large Enterprises	60%
Medium Enterprises	25%
Small Enterprises	15%
Geographic Area	
West Europe	79%
East Europe	10%
Americas	11%

and team management. The business functions of the respondents were quite heterogeneous, but 30% were related to service and after-sales, which highly involved digital servitization. The descriptive analysis clearly shows that manufacturing companies operating in a business-to-business environment are attracted to exploiting the benefits of digital servitization. As expected, more than 50% of the respondent companies were large enterprises that were likely to have extensive resources and to exert significant efforts toward investing in the transformation of their businesses. Most of the respondent companies came from Western Europe, but slight attention was also paid to digital servitization in East Europe and the Americas.

The service business portfolios, digital technology adoption, and share of revenue generated by services in the participating companies are reported in Table 3. All companies show diversified service businesses, underlining the strategic role of services in driving business growth. In detail, product-related and transactional-based services are the most in-demand, respectively, SO1 (90%), SO2 (89%), and SO3 (86%). Compared to the other categories, all companies show little interest in SO4 (35%), which demands close and continuous client relationships. However, long-term relationship-based services SO5 are more common in the service portfolios of the companies (68%), indicating the attempt to expand their service offerings with a relational focus. Notably, these services are built on existing competencies and do not radically alter the business model. Although they are widespread, the revenue generated by their sales does not exceed 25% of the total revenue share. This is particularly true when looking at the revenue share derived from multi-year service sales, in which 62% of the companies receive no more than 10% of the revenue share. This is not surprising, considering that SO4 and SO5 are less spread than SO1, SO2, and SO3, which have a transactional nature. This underscores the importance of traditional transactional service models in the companies' revenue strategies. However, multi-year services should be sources of recurring revenue and should consequently be able to cover a high revenue share.

The adoption of digital technologies in service offerings was also investigated, resulting in an overall low spread among the companies in the sample. Only IIoT appears to be adopted by more than half of the companies (53%), confirming the literature, followed by cloud computing (44%) and cybersecurity (38%), albeit to a lesser extent. More advanced technologies, such as mixed reality, simulation, AI, advanced manufacturing solutions, and AM, have limited adoption, as already investigated by Paschou [16].

Finally, the total sample was analyzed, taking into consideration the five areas of digital servitization research based on Pirola [35]. The mean values for each research area are reported in Table 4. Since the responses were based on a four-point Likert scale (1 = strongly disagree, 4 = strongly agree), lower values close to 1 indicate that a company does not embrace the practice in question, suggesting critical barriers to implementation. Conversely, higher values close to 4 suggest that the company has fully implemented the action as part of its digital servitization transformation. The analysis reveals that our sample consists of companies facing challenges in both the assessment

Table 3. Other characteristics (Source: the authors)

Characteristics	Percentage %
Service offerings	
(SO1) Spare parts	90%
(SO2) Repairs, warranties, maintenance, retrofit, and upgrading	89%
(SO3) Training, consultancy, and engineering	86%
(SO4) Leasing, renting, sharing, and pooling	35%
(SO5) Long-term maintenance contracts, pay-per-use, full-service contracts, and outcome-based contracts	68%
Digital Technologies	
Additive manufacturing (AM)/3D printing	14%
Advanced manufacturing Solutions	13%
Artificial intelligence (AI)/machine learning (ML)	18%
Big data analytics	30%
Cloud computing	44%
Cybersecurity	38%
(Industrial) internet of things (IIoT)	53%
Mixed reality	25%
Simulation of connected machines	23%
Transactional Service Sales: Share of revenue	
0%–10%	30%
11%–25%	33%
26%–50%	15%
51%–75%	3%
76%–100%	3%
Multi-year Service Sales: Share of revenue	
0%–10%	62%
11%–25%	12%
26%–50%	8%
51%–75%	2%
76%–100%	1%

and PSS design areas; this means that they lack tools and methods for supporting their PSS decisions and designing improved or completely new services. Although there is a noticeable but modest increase in mean values, increased behaviors are seen in knowledge management throughout the life cycle, the strategy and business model, and sustainability. A key finding from this analysis is that all companies acknowledge the potential benefits of digital services in the sustainability domain, highlighting a shared understanding of the strategic importance of sustainability in digital servitization.

Considering the total sample, it is possible to assess that the digital servitization practices are only partially implemented, and it is not possible to capture the variability in the behaviors. This was then addressed by the cluster analysis as described in the following section.

Table 4. Mean values (1 = strongly disagree; 4 = strongly agree) of the responses on the five areas of investigation. (Source: the authors)

Framework [35]	Mean values (n = 102)
Digital servitization strategy and business model elements	2.85
PSS design methods and tools	2.64
Assessment tool for PSS decisions and predicting performance	2.62
Knowledge management along the life cycle	2.72
Sustainable business models and digital servitization	2.98

4.2 Clusters' description

As described in the methodology section, the cluster analysis performed in this study was based on the responses to questions Q0 to Q27, identified by analyzing the literature on digital servitization [35].

The mean values for each response are reported in Figure 3, while the comparison between clusters focusing on the five areas separately is reported in *Appendix* B. The initial analysis of the mean values of the five main areas, similar to that conducted on the totality of the sample, as reported in Table 5, reveals that the clusters behave differently from one another; in particular, Cluster 3 (including 48 companies) is consistently behind Clusters 2 (including 29 companies) and 1 (including 25 companies) throughout the digital servitization process. Cluster 3 displays the same challenges and trends identified for the entire sample, although the means are reduced. On the other hand, Clusters 1 and 2 differ considerably from the averages. Furthermore, distinct approaches in how they address the transformation process are observed within Clusters 1 and 2. A detailed examination of each area was conducted to identify specific levels in how digital servitization practices are implemented. To better interpret these findings, the mean values were mapped onto implementation levels according to a defined range of values derived by evaluating the lowest and highest mean values listed in Table 5. This led to the creation of a five-level implementation scale, with "not implemented" including values below the lowest value from Table 5, 2.13 (minimum of Cluster 3), "minimally implemented" encompassing values between 2.13 and 2.61 (maximum of Cluster 3), followed by "moderately implemented" covering values between 2.61 and 3.01 (minimum value of Cluster 1), "largely implemented" covering values between 3.01 and 3.33 (maximum between Cluster 1 and 2), and "fully implemented" exceeding 3.33.

We found that Cluster 3 shows criticalities in generating revenue from digital services (Q1), effectively communicating the value of digital services to their customers (Q2), defining a proper digital servitization strategy (Q6), and consequently establishing an ecosystem of collaboration to successfully implement digital servitization transformation (Q7, Q8), as well as securing a budget specifically allocated for the creation of digital services (Q11). However, the manufacturing companies in Cluster 3 appear to recognize the value of digital services (Q3, Q4, Q5) and for these reasons, they initiate organizational-level efforts to build new competencies within the business (Q9) and outsource complementary ones to external partners (Q10). By contrast, the challenges described above seem resolved for Cluster 2. Its key elements rely on having a well-defined strategy (Q6), cultivating relationships with information and operational technology providers (Q7), developing new competencies internally and externally (Q9, Q10), and allotting a dedicated budget for digital service development (Q11). Cluster 1, while not as prepared as Cluster 2 in terms of strategies and business model elements (Q6, Q9, Q10), excels in communicating with customers (Q2) and is financially committed to digital service development (Q11). The comparison of the three clusters based on the analysis of the responses in the first area of digital servitization strategy and business model elements are reported in Table 6.

Table 5. Mean values (1 = strongly disagree; 4 = strongly agree) of the responses on the five areas of investigation divided by the three-cluster solution. * denotes the minimum and ** the maximum values for each cluster. (Source: the authors)

Framework [35]	Cluster 1 (*n* = 25)	Cluster 2 (*n* = 29)	Cluster 3 (*n* = 48)
Digital servitization strategy and business model elements	3.01 *	3.30	2.49
PSS design methods and tools	3.31	2.83	2.17
Assessment tool for PSS decisions and predicting performance	3.21	2.93	2.13*
Knowledge management along the life cycle	3.17	3.14	2.23
Sustainable business models and digital servitization	3.30	3.33**	2.61**

Table 6. Cluster comparison on digital servitization strategies and business model elements using the five-level implementation scale

Actions	Cluster 1	Cluster 2	Cluster 3
Revenue generation from digital services (Q1)	Moderately implemented	Largely implemented	Minimally Implemented
Customer communication (Q2)	Moderately implemented	Moderately implemented	Not Implemented
Digital servitization strategy (Q6)	Implemented	Fully implemented	Not Implemented
Collaboration ecosystem (Q7)	Moderately implemented	Largely implemented	Minimally Implemented
Budget allocation (Q11)	Fully implemented	Fully implemented	Minimally Implemented
Internal competency development (Q9)	Largely implemented	Fully implemented	Moderately implemented
External competency development (Q10)	Largely implemented	Fully implemented	Moderately implemented

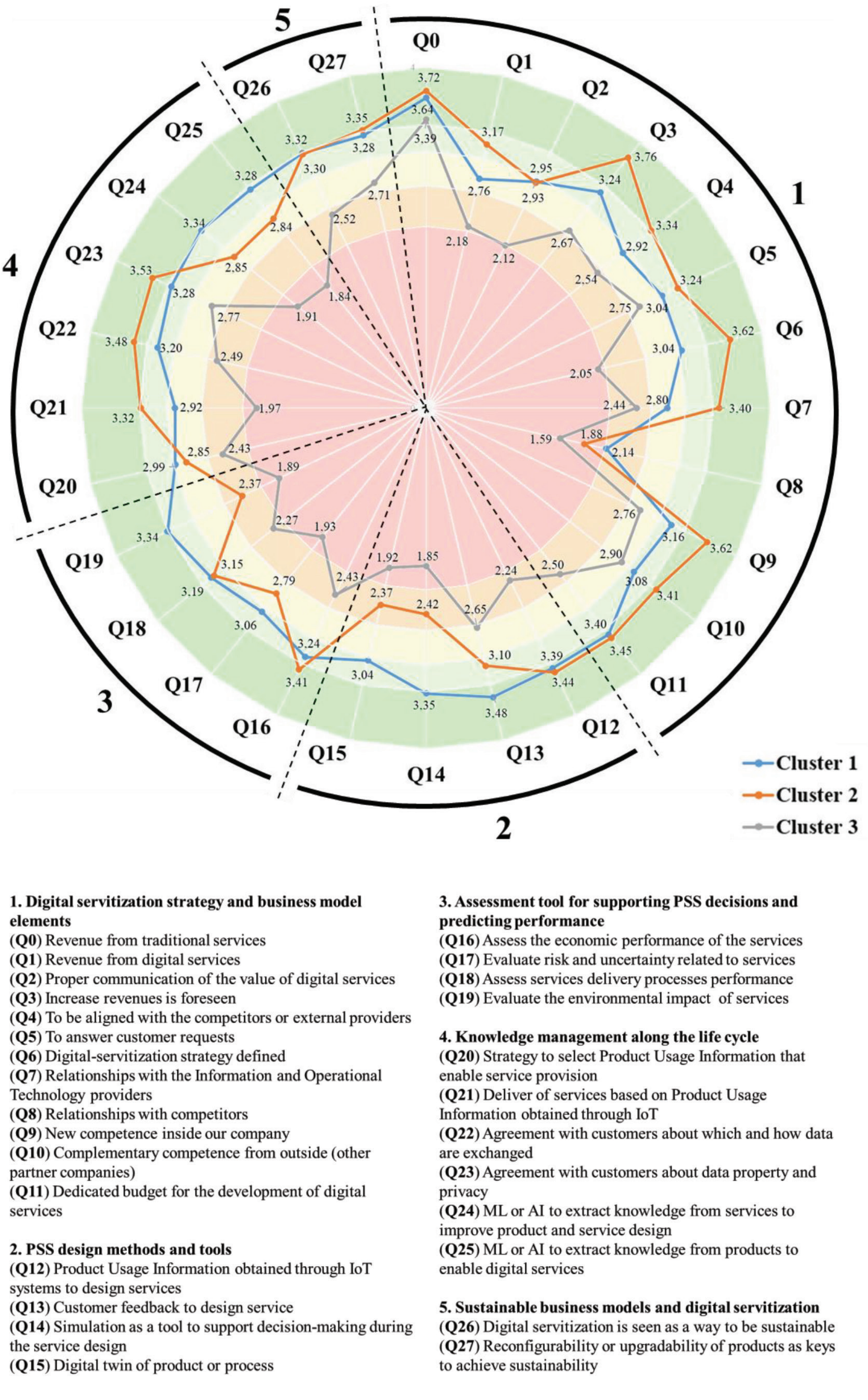

Figure 3. Q0 to Q27 responses' mean values (1 = strongly disagree; 4 = strongly agree) divided by the three-cluster solution. The three clusters were tested through one-way ANOVA, and they showed significant differences among them for all variables, except Q0 (Source: the authors)

The design methods and tools also constitute a distinguished area among the three clusters. Cluster 1 is advanced, leveraging data acquired through IIoT systems (Q12) and customer feedback (Q13) to design services. During the design phase, it uses decision-supporting tools, such as simulation (Q14), and adopts digital twins for delivering service offerings (Q15). Cluster 2 also uses data obtained through IIoT systems for structuring services; it provides digital twins of their products and processes to offer services but to a lesser extent and pays minor attention to decision-supporting tools. On the contrary, Cluster 3 exhibits low mean values in this area, possibly because of a low level of implementation of practices, both concerning service design, which remains a challenge for many companies, and fully harnessing data and decision support systems since the early stages of the product–service life cycle. In summary, Cluster 1 can rely on fully implemented service design practices partially or not implemented by Cluster 2 and limited in Cluster 3, as reported in Table 7.

Clusters 1 and 2 show similar behaviour in adopting assessment tools for supporting PSS decisions and predicting performance. Both clusters include metrics for evaluating economic performance (Q16), risks and uncertainty (Q17), and the performance of the service delivery process (Q18). However, notable distinctions emerge when evaluating the environmental impacts of services (Q19). Specifically, Clusters 2 and 3 lack the necessary measurements, whereas Cluster 1 is notably better equipped. Cluster 3 appears to be the least prepared in the area, as reported in Table 8.

The results in knowledge management along the life cycles of products and services unveil that Clusters 1 and 2 have defined strategies to select product usage information for enabling service provision (Q20), but they diverge in their approaches. Cluster 2 distinguishes itself through its strong managerial efforts in structuring customer agreements about data property and privacy (Q23) and adopting rules governing data exchange (Q22). Nevertheless, it appears to lag in the utilization of ML or AI to extract knowledge that is functional for service delivery (Q24, Q25). Cluster 1 takes the lead in these specific areas, indicating particular attention and focus on leveraging technology to gain an in-depth understanding of its products and thus offer personalized services while manufacturing companies in Cluster 3 are positioned in a second wave of progression (see Table 9).

Table 7. Cluster comparison on design methods and tools using the five-level implementation scale

Actions	Cluster 1	Cluster 2	Cluster 3
IIoT data usage for design (Q12)	Fully implemented	Fully implemented	Minimally implemented
Customer feedback integration (Q13)	Fully implemented	Largely implemented	Moderately implemented
Decision support tools, including simulation (Q14)	Fully implemented	Minimally implemented	Not Implemented
Digital twin implementation (Q15)	Largely implemented	Minimally implemented	Not Implemented

Table 8. Cluster comparison on assessment tools for supporting PSS decisions and predicting performance using the five-level implementation scale

Actions	Cluster 1	Cluster 2	Cluster 3
Economic performance (Q16)	Largely implemented	Fully implemented	Minimally implemented
Risk and uncertainty (Q17)	Largely implemented	Moderately implemented	Not implemented
Service delivery performance (Q18)	Largely implemented	Largely implemented	Minimally implemented
Environmental impact (Q19)	Fully implemented	Minimally implemented	Not implemented

Table 9. Cluster comparison on knowledge management along the life cycle using the five-level implementation scale

Actions	Cluster 1	Cluster 2	Cluster 3
Product usage data selection strategy (Q20)	Moderately implemented	Moderately implemented	Minimally implemented
Product usage data for delivery services (Q21)	Moderately implemented	Largely implemented	Not implemented
Data exchange rules (Q22)	Largely implemented	Fully implemented	Minimally implemented
Customer agreements (data property & privacy) (Q23)	Largely implemented	Fully implemented	Moderately implemented
AI/ML for knowledge extraction (Q24, Q25)	Fully implemented	Partially implemented	Not implemented

Sustainable business models and digital servitization are overlapping areas of interest for companies, as has been extensively underlined in recent literature. This is confirmed by the results, which reveal a similar approach adopted by both Clusters 1 and 2 in considering digital servitization as a means to implement sustainable solutions (Q26). Specifically, they suggest reconfigurability or upgradability as a key business strategy to achieve sustainable solutions (Q27). To a lesser extent, Cluster 3 also acknowledges the potential for achieving sustainable goals through service-oriented business models but does not implement digital services in this direction. The comparison of the clusters based on these results is reported in Table 10.

4.3 Clusters' characteristics

Once the clusters were defined, we thoroughly examined their characteristics by studying how they are composed in terms of service offering, digital technologies adoption, and the other characterization variables explained in Section 3.1. Once again, the *p*-values were checked. This analysis yielded the following key insights.

- **Diversity in Service Offerings:** The three clusters do not significantly differ in terms of service offerings (p-value > 0.05), and variations emerge in their approaches to innovative service offerings that transcend typical transactional paradigms. All clusters align with the average values of the total sample, confirming that their service portfolios are highly diversified. However, Cluster 1 is dominant in product-oriented advice and consultancy services (SO3) (96%), while Cluster 2 excels in all other service offerings (see Table 11).
- **Digital Technology Adoption:** Conversely, the clusters differ in the adoption of digital technologies in their service offerings (p-value < 0.05). Clusters 1 and 2 show a higher level of adoption of digital technologies, but differences between the two clusters can be observed. Specifically, Cluster 2 demonstrates a stronger adoption of IIoT, big data analytics, cloud computing, and AI, which represent the constitutive elements of their service offerings. This aligns with the composition of Cluster 2's service portfolio, where these technologies are integral to delivering services such as maintenance and performance-based contracts [16], [59]. Companies belonging to Cluster 1, although generally having a slightly lower level of adoption, appear to be more inclined to experiment with various technologies (e.g., AM and advanced manufacturing solutions) not only as enablers of service processes but as fundamental parts of the value proposition. Cluster 3 is not that ready, with a significantly lower adoption of these technologies in its service offerings. For the comparison between the clusters, see Table 12.
- **Sector:** The three clusters do not significantly differ in terms of sector composition (p-value > 0.05). The trend observed in the total sample is also verified in each cluster, predominantly composed of companies from the capital goods sector. Cluster 2 has a higher percentage of capital goods industries than the other two

Table 10. Cluster comparison on sustainable business models and digital servitization using the five-level implementation scale

Actions	Cluster 1	Cluster 2	Cluster 3
Digital servitization for sustainability (Q26)	Largely implemented	Largely implemented	Minimally implemented
Reconfigurability/upgradability (Q27)	Largely implemented	Fully implemented	Moderately implemented

Table 11. Service offering of the three clusters. The percentage values are computed based on the relative dimension of the specific cluster, and the delta is calculated considering the distance from the average value of the total sample (Source: the authors)

	Percentage % (delta with avg % value)		
Service offerings	Cluster 1	Cluster 2	Cluster 3
(SO1) Spare parts	91% (+1%)	93% (+3%)	88% (−2%)
(SO2) Repairs, warranties, maintenance, retrofit, upgrading	76% (−13%)	97% (+8%)	92% (+2%)
(SO3) Training, consultancy, engineering	96% (+10%)	86%	81% (−5%)
(SO4) Leasing, renting, sharing, pooling	28% (−7%)	41% (+6%)	35%
(SO5) Long-term maintenance contracts, pay-per-use, full-service contracts, and outcome-based contracts	72% (+4%)	72% (+4%)	63% (−5%)

clusters. On the contrary, Cluster 1 includes a higher percentage of consumer goods industries. The comparison is reported in Table 13.

- **Dimension:** The three clusters do not significantly differ in terms of dimension composition (*p*-value > 0.05). However, we can observe in Table 14 a higher presence of SMEs in Cluster 3 (50%, compared to 40% in Cluster 1 and 34% in Cluster 2) and a significant percentage of large companies in Cluster 2 (76%).
- **Revenue Generation:** Companies in each of the three clusters show a similar trend in revenue generation from the sale of services, which still covers the lower part of revenue shares (from 0% to at least 50%). Based on these variables, the three clusters do not significantly differ from one another (p-value > 0.05). It can be observed in Table 15 that the companies are still focused on selling and generating revenue from transactional services rather than multi-year service sales; looking at the first three ranges of revenue share, the percentage of companies is more distributed in the transactional service cases than in the multi-year services where more the than 50% of the companies are just generating the 0%-10% of the total revenues. Compared with the two other clusters, Cluster 2 seems to be able to derive a slightly more significant revenue share from transactional and multi-year service sales; 83% of Cluster 2's companies receive at least 50% of their revenue from transactional services versus 76% for both Cluster 1 and 70 % for Cluster 3. The same trend is observed for multi-year service sales (90% of Cluster 2 against 72% of Cluster 1 and 81% of Cluster 3).

Table 12. Digital technologies adoption of the three clusters. The percentage values are computed based on the relative dimension of the specific cluster, and the delta is calculated considering the distance from the average value of the total sample (Source: the authors)

	Percentage % (delta with avg % value)		
Digital technologies	Cluster 1	Cluster 2	Cluster 3
AM/3D printing	28% (+14%)	17% (+3%)	4% (−10%)
Advanced manufacturing solutions	24% (+11%)	14% (+1%)	6% (−7%)
AI/ML	20% (+2%)	34% (+16%)	6% (−12%)
Big data analytics	48% (+18%)	52% (+22%)	8% (−22%)
Cloud computing	56% (+12%)	69% (+25%)	23% (−11%)
Cybersecurity	60% (+22%)	52% (+14%)	19% (−19%)
IIoT	68% (+15%)	90% (+37%)	23% (−30%)
Mixed reality	32% (+7%)	34% (+9%)	17% (−8%)
Simulation of connected machines	24% (+1%)	34% (+11%)	15% (−8%)

Table 13. Sector of the three clusters. The percentage values are computed based on the relative dimension of the specific cluster, and the delta is calculated considering the distance from the average value of the total sample (Source: the authors)

	Percentage % (delta with avg % value)		
Sector	Cluster 1	Cluster 2	Cluster 3
Capital Goods (Aerospace and Defense, Construction, Machinery, Medical, Electronics)	72% (-6%)	86% (+8%)	77% (-1%)
Consumer (Durable) Goods (Consumer Electronics, Domestic Appliances)	12% (+2%)	7% (-3%)	10%
Consumer (Non-Durable) Goods (Food, Beverage, Tobacco, Household Products)	8% (+3%)	0% (-5%)	6% (+1%)
Oil and Gas, Energy, Chemicals, and Materials (Plastics, Metals, Mining, Paper)	8% (+3%)	7% (+2%)	2% (-3%)
Pharma, Biotech, and Life Sciences	0% (-2%)	0% (-2%)	4% (+2%)

Table 14. Dimension of the three clusters. The percentage values are computed based on the relative dimension of the specific cluster, and the delta is calculated considering the distance from the average value of the total sample (Source: the authors)

	Percentage % (delta with avg % value)		
Dimension	Cluster 1	Cluster 2	Cluster 3
Large enterprises	60%	76% (+16%)	50% (−10%)
Medium enterprises	28% (+3%)	10% (−14%)	31% (+7%)
Small enterprises	12% (−4%)	14% (-2%)	19% (+3%)

Table 15. Share of revenues for services of the three clusters. The percentage values are computed based on the relative dimension of the specific cluster, and the delta is calculated considering the distance from the average value of the total sample (Source: the authors)

	Percentage % (delta with avg % value)		
	Cluster 1	Cluster 2	Cluster 3
Transactional service sales: Share of revenue			
0%–10%	28% (−2%)	34% (+4%)	29% (−1%)
11%–25%	32% (−1%)	38% (+5%)	31% (−2%)
26%–50%	16% (+1%)	21% (+6%)	10% (−5%)
51%–75%	4% (+1%)	0% (−3%)	4% (+1%)
76%–100%	0% (−3%)	3%	4% (+1%)
Multi-year service sales: Share of revenue			
0%–10%	52% (−10%)	69% (+5%)	63% (+1%)
11%–25%	12%	14% (+2%)	10% (−2%)
26%–50%	8%	7% (−1%)	8%
51%–75%	0% (−2%)	7% (+5%)	0% (−2%)
76%–100%	0% (−1%)	0% (−1%)	2% (+1%)

5. Discussion

Companies are shaping their strategic, tactical, and operational activities to pursue the digital servitization process. Through a literature review, this study investigated the best practices, challenges, and opportunities for digital servitization. Driven by the need to broadly explore the actions and best practices of companies implementing digital servitization, this study adopted a quantitative research method. This approach was used to gather data and cluster analysis was adopted to empirically define some clusters with specific behaviors to embrace digital servitization. Guided by the digital servitization actions outlined in the literature, the study revealed the presence of three distinct clusters. These clusters were further examined using additional survey variables, leading to the characterization of three unique digital servitization business typologies, which are named and described in the following sections.

5.1 Cluster 1: digital experimentalists

Cluster 1 represents manufacturing companies that are actively exploring and experimenting with digital technologies in their service offerings; for this reason, we named them *digital experimentalists*. Manufacturing companies in this cluster show a highly diversified service offering portfolio, augmented by the widespread integration of digital technologies. They appear to have embraced the digital servitization process, starting from the investigation of the potential of data exploitation and analysis that previous literature has identified as a *bottom-up* or *push technology-based* approach [8]. They have implemented a strategy for selecting product usage information derived from IIoT systems as the basis for developing new services or improving existing ones. Additionally, customer feedback is leveraged during the development phase (Q13). However, there is no well-defined digital servitization strategy supporting the identification of key business model elements. Cluster experiments with different digital technologies, such as ML or AI, seem to be used for constructing knowledge to enable and improve services (Q24, Q25). Simulation techniques are utilized for decision support, while the digital twins of products and processes facilitate rapid responses to changes (Q14, Q15). The companies in this cluster also extract and compute data to assess the economic and environmental impacts of services (Q16, Q19) and evaluate the associated performance and risks (Q17, Q18). Therefore, digital experimentalists appear to adopt digital technologies as decision support tools (mainly based on simulation) to assess PSS overall performance and use them as enablers of improved smart PSS. Exploiting digitalization, they strongly believe in enhancing sustainability (Q26, Q27). However, these companies are still addressing challenges at the strategic and business model levels, such as a clear strategy, lack of competencies and digital and business model skills, multi-actor partnerships, and alignment of the value system as suggested by previous studies [8], [12], [14], [15], which however do not constitute such critical for successfully embracing the digital servitization process. Indeed, the bottom-up approach is most commonly used by product-centric companies. The primary problem stems from these companies developing their strategies on existing assets. This approach allows experimentation based on the considerable amount of data gathered through digital technologies, which promotes good communication of the value of digital services (Q2), but this does not necessarily lead to high revenue. This aspect is in contrast with the revenue generation and profit growth derived from digital servitization as suggested by the literature [11], [15], [18], [22], [60]. Digital experimentalists are mainly large companies that have many resources for acquiring or developing technologies, but the analysis shows that this dimension is not statistically significant when comparing the cluster with the others. They are leaders in training, consultancy, and engineering services that benefit from the knowledge extracted from products by digital technologies and customer feedback (Q13). However, once again, the service offerings of the three clusters do not significantly differ.

5.2 Cluster 2: strategic pioneers

Cluster 2 focuses predominantly on business models and strategy, particularly excelling in the digital servitization domain, as defined by Pirola [35]. Companies in this cluster are called *strategic pioneers*. Manufacturing companies belonging to this cluster have a clear view of the added value that digital services offer, internally in terms of revenue increase (Q1, Q3) and facing market competition (Q4), and externally in terms of responding to customers' needs (Q5). Companies have defined and integrated strategies to drive their business model transformation (Q6), which is suggested as a key best practice of digital servitization [7]. They possess established, well-defined organizational structures and cultivated competencies internally (Q9) or externally (Q10) tailored to digital services, as suggested by existing studies [5], [7], [9]. Strategic pioneers have also improved the ecosystem by partnering with other companies (Q7), another element discussed in the literature [7], [9]. They have focused on adopting specific technologies (Q12) to enable new services (i.e., IIoT), which appear to be evolutionary extensions of well-established services, such as maintenance contracts. To enable this, they have addressed important challenges related to data protection and security issues, as highlighted by the previous literature [12], [14], [15]. The high adoption of cybersecurity technology also demonstrates this. However, the analysis reveals that, despite the companies' investments in data extraction and analysis technologies, they have not yet fully optimized the utilization of the data obtained to extract knowledge (e.g., complementing data extraction with AI) or to assess PSS performance. Similar to the manufacturing companies in Cluster 1, those in this cluster strongly see digital services as a means to be sustainable (Q26, Q27). However, contrary to digital experimentalists, strategic pioneers adopt a *top-down or pull technology-based* approach to digital servitization, which is a systematic approach that follows a defined business logic grounded in the value architecture mechanism [8]. They take advantage of adopting digital technologies that are more familiar with and of value to customers while addressing the digital servitization trend. This helps companies build the necessary competencies and resources to create new value propositions for digital services. They are predominantly large companies with very diversified service portfolios and monetize well from providing services.

5.3 Cluster 3: digital servitization novices

Cluster 3 represents companies in the initial stages of the digital servitization journey; it has the lowest mean values in each of the five research areas. Therefore, the companies in this group are called *digital servitization novices*. Cluster 3 includes beginners and manufacturing companies that have just started their digital servitization processes, similar to the level 1 beginner suggested by the maturity model of Paschou [31]. While they recognize the potential of incorporating digital technologies into their service offerings, they lack clear business model skills and do not adhere to defined strategies (Q1, Q2, and Q6). Neither do they have guidelines for utilizing product usage information (Q12) or for assessing the risks (Q17) and environmental performance of services (Q19). Not surprisingly, the other main weakness of digital servitization novices is their lack of design (Q24, Q25) and decision-supporting tools (Q14, Q15), such as AI and simulations or digital twins. The manufacturing companies in Cluster 3 are mainly small organizations that may not have the resources (e.g., financial) to adopt advanced digital technologies. However, company dimension is not a significant distinguishing or characterizing factor among clusters, so by working on their weaknesses, those companies in Cluster 3 can achieve the same digital servitization outcomes as digital experimentalists and strategic pioneers. The positioning of the three clusters considers the main distinguishing drivers of manufacturing firms' digital servitization, as suggested by this analysis and shown in Figure 4. Further research can specifically address the steps that a company should undertake to accomplish this purpose, which can be rather straightforward, as highlighted by the presence of different successful digital servitization approaches in Clusters 1 and 2.

6. Conclusions

The digital servitization of manufacturing companies represents a profound transformation requiring significant changes across strategic, tactical, and operational levels. While prior research has identified best practices and explored challenges and opportunities in this domain, there remains a lack of quantitative evidence to support whether manufacturing firms adopt digital servitization uniformly, raising questions about their approaches and behaviors. This study addressed these questions by investigating how manufacturing companies approach digital servitization, identifying the main actions driving their strategies, and defining distinct business typologies.

This study's theoretical contribution is using quantitative research method, including a survey targeted at manufacturing companies worldwide for collecting data, and the consequent cluster analysis to assess and further explain how manufacturing companies embrace the digital servitization process. The questionnaire was designed by a group of international experts in the field based on the highlighted literature on digital servitization. As the first type of analysis adopted, cluster analysis was performed to naturally determine different groups with the same behaviors in terms of digital servitization actions [35]. The cluster analysis revealed the presence of three different business typologies that approach digital servitization

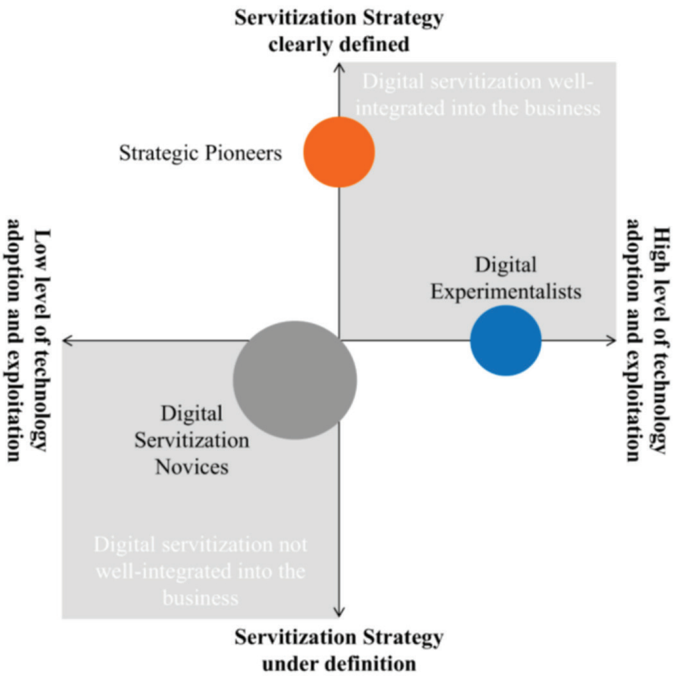

Figure 4. Positioning of the three clusters. The bigger the circle, the higher the size of the cluster. (Source: the authors)

transformation with different behaviors: (i) manufacturing companies that have embraced this process by focusing on the data obtained using digital technologies—called digital experimentalists; (ii) those that have embraced the digital servitization process by focusing on changing their business models—called strategic pioneers; and (iii) companies that have just started their processes toward digital servitization—called digital servitization novices. The first two have found a way of taking advantage of digital technologies to provide new, advanced services, but they follow two different approaches that have been defined as bottom-up (or push technology-based approach) and top-down (or pull technology-based approach). Both lead to the same digital servitization outcomes. The quantitative approach also allowed for a broad cross-business investigation, which did not show significant differences in the service offerings, revenue generation, sector, and size of the companies belonging to the different clusters. Only the adoption level of digital technologies among the clusters appeared to be a distinguishing element for the business typologies. Digital servitization novices are clearly in their first wave of digitalization of their service offerings, while the other two business typologies use the technologies in two different ways throughout the digital transformation of their service design, delivery, and related business model elements.

From a practical perspective, the questionnaire itself represents a practical instrument that managers can exploit as an assessment tool for positioning their companies as digital experimentalists, strategic pioneers, digital servitization novices, or even in a new cluster. Importantly, it may help understand companies' strengths and weaknesses when adopting digital servitization in the five main areas constituting the fundamentals of this analysis. Therefore, it can help managers understand the actions that are missing in their digital servitization approach and, on the contrary, the strengths and the approach (bottom-up or top-down) they can leverage to achieve more consolidated digital servitization outcomes.

However, the study is limited by its sample size and geographical scope, primarily focused on Europe, as well as potential sampling bias from exclusion criteria. Future research could address these limitations by expanding the sample size, targeting underrepresented regions, and refining the sampling strategy to identify new behaviors and typologies.

Finally, as this study contributes to defining business typologies based on the main distinguishing drivers of the digital servitization process, future research can also delve into identifying the concrete steps (e.g., maturity model) that manufacturing companies from the digital experimentalist and strategic pioneer clusters have carried out to implement a successful digital servitization covering the three different scopes (strategic, tactical, and operational) separately. The latter could be very helpful for defining companies' servitization roadmaps and change management actions.

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Appendix A

The framework and investigated questions were used as a basis for the segmentation.

Research areas [35]	Question Category	Question
Digital Servitization Strategy and Business Model	How do I communicate the value and get paid for the digital services?	Q0: Our company generates revenue from traditional services Q1: Our company generates revenue from digital services Q2: Our company is properly communicating to customers the value of digital services
	Why are companies developing digital services? Which advantages are foreseen?	Q3: Our company is investing in digital services since the potential to increase revenues is foreseen Q4: Our company is investing in digital services to be aligned with the competitors or external providers Q5: Our company is investing in digital service to answer customer requests Q6: Our company has defined a Digital Servitization strategy
	How relevant is the collaboration to properly implement a digital servitization transformation?	Q7: To develop a digital service(s), our company has developed strong and long-term relationships with the Information and Operational Technology (e.g., PLC, SCADA) providers Q8: To deliver digital service, our company has developed relationships with competitors
	How the company is organized to reach the advantage foreseen?	Q9: To develop and deliver digital service, new competence(s) have been developed inside our company Q10: To develop and deliver digital service, our company leverages complementary competence(s) from outside (other partner companies) Q11: Our company has a dedicated budget for the development of digital services
PSS Design Methods and Tools	How the data are used to design new digital services?	Q12: Our company uses Product Usage Information obtained through IoT systems to design services (e.g., threshold for maintenance) Q13: Our company use customer feedback (e.g., reports, claims, social) to design service that meets customer needs Q14: Our company is adopting simulation as a tool to support decision-making during the design of the service Q15: Our company is offering digital service through the digital twin of product or process
Assessing tools for PSS decisions	What are the key aspects the company measures of the service?	Q16: Our company has metrics to assess the economic performance of the services Q17: Our company has metrics to evaluate risk and uncertainty related to services Q18: Our company has metrics to assess the performance of service delivery processes Q19: Our company has metrics to evaluate the environmental impact of services
Knowledge Management along the Lifecycle	How are companies managing the data to offer digital services? (collection, analysis etc.)	Q20: Our company has defined a strategy to select Product Usage Information that enables service provision Q21: Our company deliver services based on Product Usage Information obtained through IoT systems Q22: Our company has an agreement with customers about which and how data are exchanged Q23: Our company has an agreement with customers about data property and privacy Q24: In our company, we are using ML or AI to extract knowledge from services we provide (e.g., service reports, customer assistance tickets) to improve product and service design Q25: In our company, we are using ML or AI to extract knowledge from products to enable digital services
Sustainable Business Model	Is service a key to being more sustainable?	Q26: Digital servitization in our company is seen as a way to be sustainable Q27: Reconfigurability or upgradability of products is seen as a key strategy to achieve sustainable solutions

Appendix B

Appendix B includes all the graphs drawn based on the mean values divided into the five areas of research used to frame the cluster analysis. The graphs compare the three clusters identified by the study.

- **Figure B1** addresses the digital servitization strategy and business model elements area.
- **Figure B2** addresses the PSS design methods and tools area.
- **Figure B3** addresses the assessment tools for supporting PSS decisions and predicting performance area.
- **Figure B4** addresses the knowledge management along the life cycles of products and services area.
- **Figure B5** addresses the sustainable business models and digital servitization area.

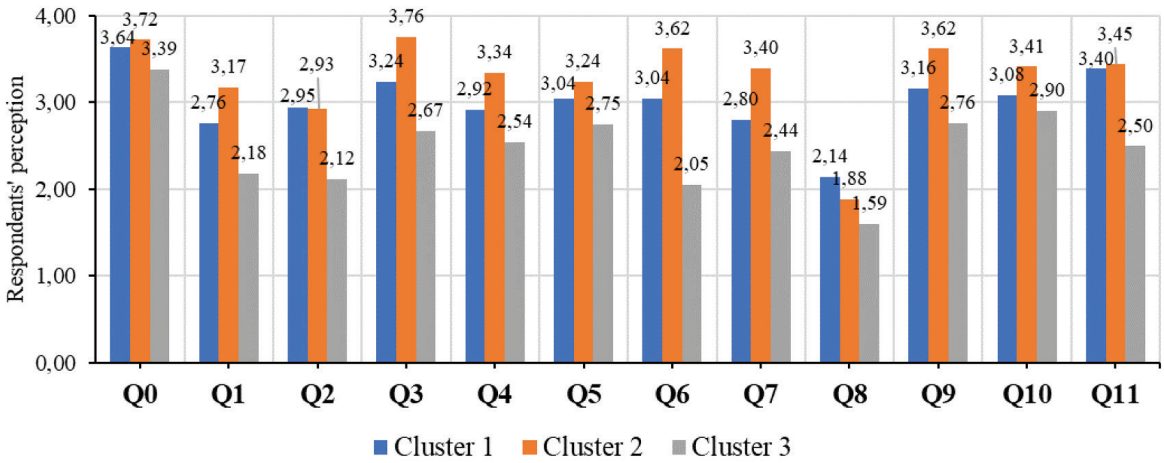

Figure B1. Mean values of the responses on digital servitization strategy and business model elements (1 = strongly disagree; 4 = strongly agree) divided by the three clusters (Source: the authors)

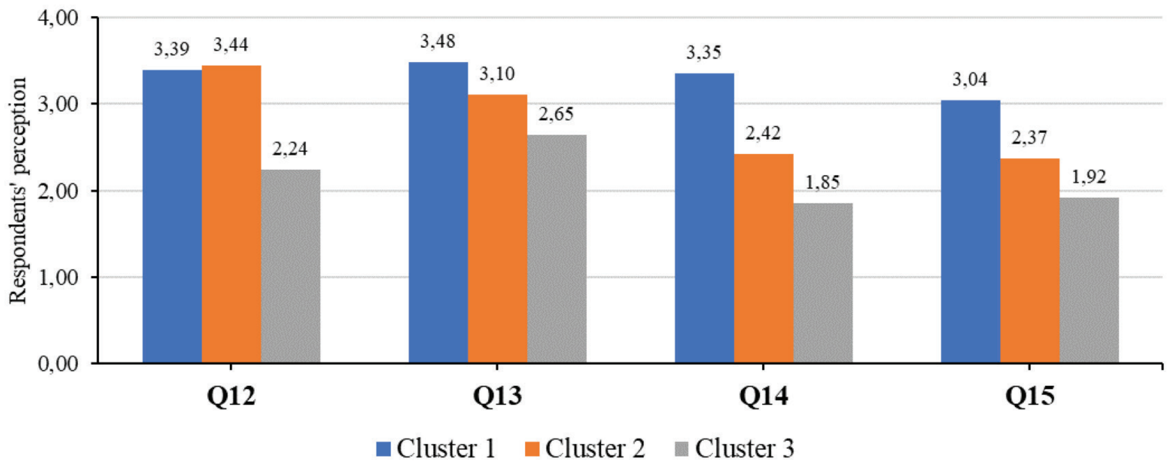

Figure B2. Mean values of the responses on innovative PSS design methods and tools with an emphasis on the digital component (1 = strongly disagree; 4 = strongly agree) divided by the three clusters (Source: the authors)

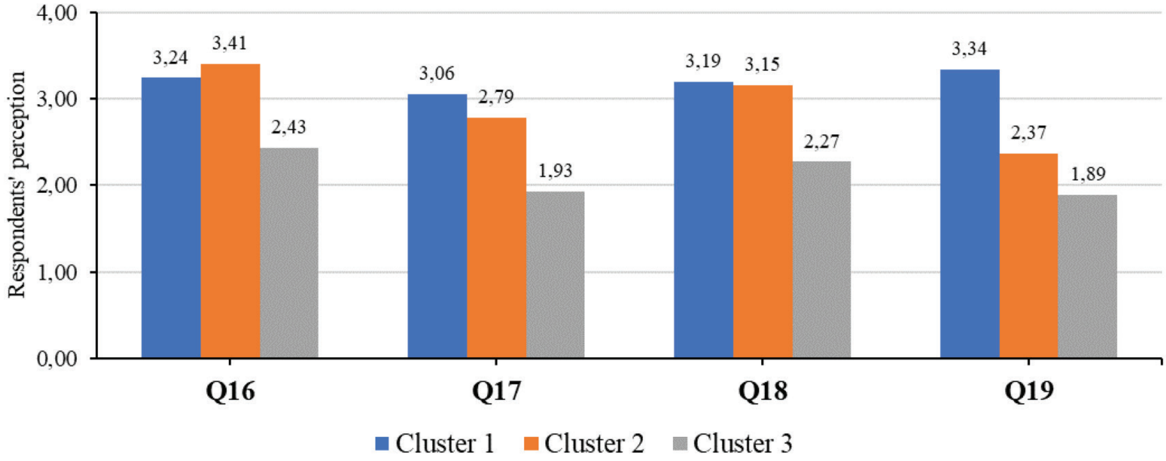

Figure B3. Mean values of the responses on assessment tools for supporting PSS decisions and predicting performance (1 = strongly disagree; 4 = strongly agree) divided by the three clusters (Source: the authors)

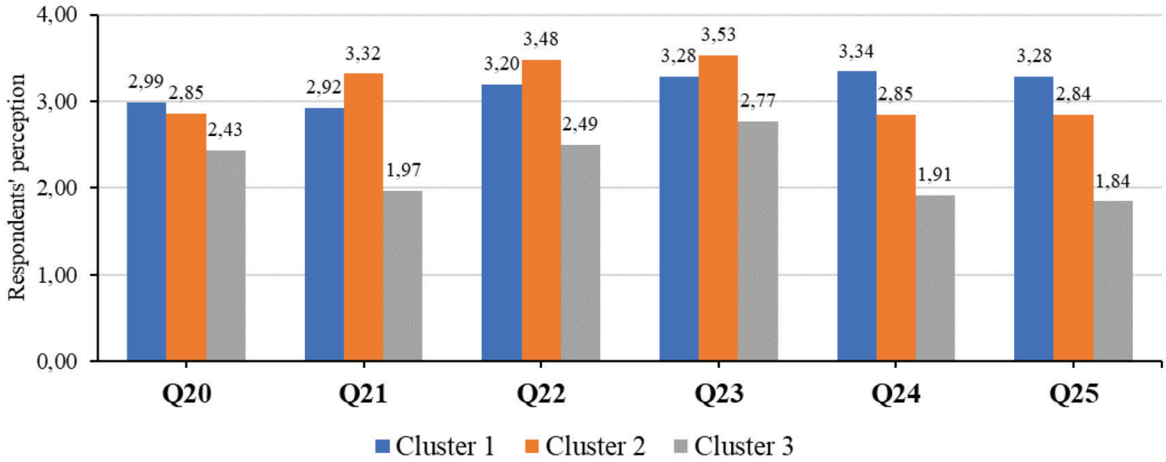

Figure B4. Mean values of the responses on knowledge management along the life cycles of products and services (1 = strongly disagree; 4 = strongly agree) divided by the three clusters (Source: the authors)

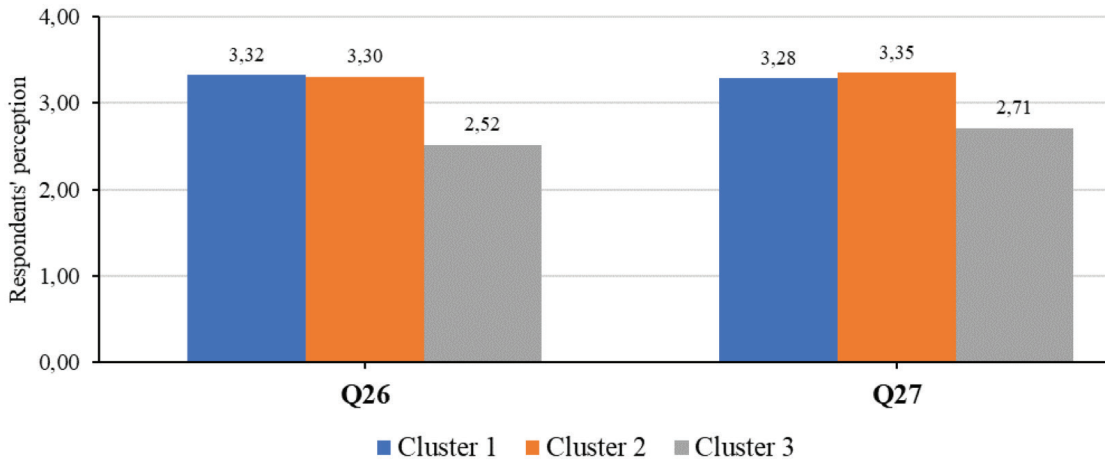

Figure B5. Mean values of the responses sustainable business models and digital servitization (1 = strongly disagree; 4 = strongly agree) divided by the three clusters (Source: the authors)