

TRIANGLE DILEMMA: NAVIGATING THE DIGITAL SERVICIZATION OF MANUFACTURING IN PRODUCT-SERVICE-SOFTWARE SYSTEMS

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ABSTRACT

Purpose: This paper reviews the literature on product-service-software systems (PSSs) in the setting of servitization of manufacturing companies. Then, it uses an in-depth case-research to advance knowledge on PSSs, as a potential evolution of digital servitization.

Design/Methodology/Approach: the paper employs an extensive literature review with keywords such as *servitization, product-service system, software, platform, smart PSS, and PSSS*, to retrieve relevant studies on this subject. The research is also based on preliminary findings from a leading case manufacturer that is developing a stand-alone software business.

Findings: the study unveils the interrogatives and tensions that arise in a large industrial firm, that has a well-established business of equipment and advanced digitally-enabled services when moving to a digital products offering.

Originality/Value: the novelty of this study lies in the focus on software, as a stand-alone business, in manufacturing contexts. The research provides indications for managers and avenues for future research.

KEYWORDS: Digital Servitization; Product-Service System; Product-Service-Software System; smart solution; platform; software.

1. INTRODUCTION

Manufacturers have made substantial efforts to reshape their organisations, and capabilities and expand their service business (Baines et al., 2009). This move is termed servitization and can be defined as a strategic transformation where the business logic shifts from traditional product-dominated offerings to a combination of products and services (product-service systems, PSS) that better meet customer needs (Baines et al., 2017). Servitization can increase differentiation from rivalry, intensify customer relationships and open new sources of income (Rapaccini & Adrodegari, 2022). To deliver advanced services, manufacturing firms must set up new capabilities and reorganise their operations (Baines & Lightfoot, 2014). Digital technologies can act as a vehicle to overcome these obstacles, also providing the means to offer additional services, improve service quality and reduce operational costs (Chen et al., 2021). This combination of digital technologies to accelerate the moves of servitization has culminated in the creation of data-driven propositions, digitally enabled business models and smart PSS (Porter & Heppelmann, 2014). The literature that investigates the use of digital technologies to support servitization uses different keywords such as digital servitization (Paiola & Gebauer, 2020), smart PSS (Rapaccini et al., 2013), technology-enhanced PSS (Pezzotta et al., 2023). Common to this literature there is a “*transition towards smart solutions that enable value creation and capture through monitoring, control, optimization, and autonomous function*” (Kohtamäki et al., 2021). While the challenges associated with the integration of digital technologies in the provision of advanced services and PSS have been extensively examined (Kohtamäki, et al., 2019a), there remains however a vast and relatively unexplored territory with limited research attention in the presence of digital platforms and software that are sold as stand-alone products. This nascent trend is indicated with the term Product-Service-Software Systems (PSSs) (Huikkola et al., 2022a). The literature shows that the interplay between products, services, and software can lead to numerous internal conflicts within the company (Struwe & Slepnirov, 2023). Strong tensions can originate between the offer of a digital platform with software capabilities that allow customers to monitor their equipment and the provision of digital services from the OEM in combination with the connected equipment. In fact, from one side the development of digital technologies is core to digital servitization. On the other, it can boost some strands of new digital businesses that are independent - and somehow competing - with the PSS (Kohtamäki et al., 2022). Therefore, strong doubts remain about the effective coexistence of software as a stand-alone business in the context of digital servitization and platform-based smart services (Gebauer et al., 2021). At light of this

gap, this paper aims first to review the literature on this topic. Then, we use in-depth case-based research to advance knowledge on PSSS as a potential evolution of digital servitization. In particular, the study focuses on the conflicts between stand-alone software and digital servitization and on the capabilities and approaches to the development of PSSS. The rest of the paper is organized as follows. Section 2 provides the theoretical background, section 3 the research methodology, and section 4 the case-study findings. Section 5 concludes the paper by showing the theoretical and practical contributions and limitations, together with avenues for future research.

2. THEORETICAL BACKGROUND

In recent years, the share of manufacturing firms' turnover and value-added derived from the provision of services has increased (Kowalkowski et al., 2016). Many manufacturing firms have embarked on a process of servitization to provide integrated packages of products and services (Baines et al., 2017), also known as product-service systems (PSSs) (Rapaccini et al., 2013); a concept that requires a well-established approach of moving from a transactional business model focused mainly on the product to the incorporation of integrated services (e.g. subscription or pay-per-use model) (Paola & Gebauer, 2020), to embed the value proposition of a solution provider for the benefit of both the customer and the equipment provider. Manufacturers servitize their business models to differentiate themselves (Baines et al., 2009), increase their revenues (Gebauer et al., 2005), generate higher profits (Kohtamäki et al., 2019a), and improve their performance (Reim et al., 2015), and market value (Chen et al., 2021). What makes the current wave of servitization unique is its scope and the role of digitalization in the PSS offerings. The increasing proliferation of digital technologies has led manufacturing companies to address a particular type of servitization, which recent literature refers to as digital servitization (Kohtamäki et al., 2019b). It is a transformative process that relying on information technologies, develops and improves existing services and enables new ones (Struwe & Slepnirov, 2023) allowing the creation and acquisition of superior value (Porter & Heppelmann, 2014). This, is through new (digital) business models, new ways of (co)creating value, the generation of knowledge from data, and at the same time, the improvement of the operational and environmental performance of the company for competitive advantage (Paschou et al., 2020). The integration of digital technologies such as smart sensors, connectivity, and data analysis capabilities into physical products (Baines & Lightfoot, 2014), and the use of cloud computing, big data analytics and artificial intelligence (Ardolino et al., 2018), offers opportunities to develop unique, individualized value propositions. The literature often distinguishes such PSSs from traditional PSSs, calling them the former smart PSS or smart solutions. Despite a certain deal of ambiguity, a common requirement for most of them is the intensive use of data generated by connected objects to create automatically novel knowledge about asset productivity, optimisation, operations, and maintenance (Baines et al., 2020).

Thus, we can say that smart solutions consist of physical elements such as industrial equipment and mechatronics, intelligent elements such as software, sensors and embedded control systems, and connectivity such as ports, protocols and cloud-connected enabling networks, all enabling data-driven capabilities to describe, diagnose, predict and prescribe how the health of assets and their performance can be improved. This latter layer is the domain of breakthroughs such as machine learning algorithms, artificial intelligence, and digital twins (Huikkola et al., 2022a). Indeed, the term smart refers mostly to the software, while product-service systems refer to the solution, suggesting that product-service-software systems are equal to smart solutions (Kohtamäki et al., 2022). However, it emerges from the literature that the term 'software' of the PSSS can refer to different types of digital platforms. This topic is the subject of much attention in the servitization literature and refers to *“products, services, or technologies that act as a foundation upon which external innovators, organised as an innovative business ecosystem, can develop their complementary products, technologies, or services”* (Paschou et al., 2020). Tian et al. (2022) for example categorise digital platforms into back-end and front-end platforms, which in turn can be distinguished into analogue (non-enabling servitization, such as customer support, advice and product maintenance platforms), digital (such as online transactional platforms, or programme integration and optimisation software) and smart (combining and leveraging IoT platforms, connected products, smart manufacturing platforms and industry 4.0 solutions). The same study also suggests a step-by-step process for platform-based servitization. In line with these findings, Madanaguli et al. (2023) conceptualise the industrial digital platform business model in co-creative value creation, mutual value capture and digitally integrated value delivery, and

subdivide the different digital platforms because of industrial data integration and ecosystem actor integration into: industrial product efficiency platform, industrial transactional platform, industrial product-service platform and industrial platform ecosystem. Platforms are thus technology infrastructures that enable companies to efficiently develop, configure and deliver advanced services on an unprecedented scale, enabling them both to go beyond their product offerings and create new usage scenarios and unlock immense opportunities by facilitating synergistic interactions between multiple actors in a business ecosystem, to enable innovation and value delivery (Cenamor et al., 2017). Platform providers started with the development of monitoring services, unlocking the ability to provide active and proactive remote monitoring, and generate automated reports that served as the basis for all other more advanced platform services (early warning services, basic diagnostics and support services) (Pezzotta et al., 2023). They then evolved to optimisation services where the scope was extended from a single machine to an entire fleet, to provide customers with analytical support to eliminate or minimise risks associated with asset investment, to improve efficiency and productivity, and to reduce overall costs through advanced site management services (simulation and optimisation); thus, enabling outcome-based contracts and performance-based agreements (Jovanovic et al., 2022). In addition, currently more advanced manufacturers exploit digital platforms to develop and deliver autonomous services with dynamic adjustments to the performance of their assets to optimise their customers' strategic objectives (Eloranta et al., 2021). Platforms thereby stimulate manufacturing companies to transform their business towards digital servitization, but eventually, such platforms can become a separate form of business model by being sold and provided by manufacturers as platform-as-a-service (Gebauer et al., 2021). Indeed, despite smart solutions can lead back to embedded systems, there is also the possibility to develop, sell and distribute software offerings separately (Huikkola et al., 2022b), emphasising their role as a central component of smart PSS offerings (Kohtamäki et al., 2021). Such as in the case of servitization, the development of software, digital products and platform-based business is challenging, and most product manufacturers fail to pursue it (Kowalkowski et al., 2016). Combining product, service, and software innovations within integrated smart solutions, and aligning different development and deployment strategies and capabilities can be very difficult (Huikkola et al., 2020). Hsuan et al. (2021) show that this move can be accomplished by numerous trajectories, that have some interdependencies. Huikkola et al. (2022a) confirm these findings and present the dynamic routines for realigning the provider capabilities with the offering of smart solutions. Kohtamäki et al. (2022) conceptualize the interplay between servitization and digitization, the related ecosystem they enable, business models, and PSSS technologies; realizing a path of digital servitization toward smart solutions, needing platform ecosystem, platform orchestrator and autonomous operations. Boßmann et al. (2024) established a four-step method for the management of a hybrid portfolio, which starts with the identification of the portfolio value and company-specific objectives, analyses the balance within the portfolio, adjusts the portfolio strategy and its components, and finally allocates the relevant resources to the portfolio by consolidating the results. This consolidation is critical, as the different business units usually face contradictory goals and paradoxes when managing the adoption of PSSS (Kohtamäki et al., 2019b). Indeed, P&Ls are organised separately and with distinct development models can cause silo effects, tensions and clashes between products, services and software (Huikkola et al., 2022b). Separate structures can indeed lead to disintegration problems, tensions and clashes between P&L units, due to conflicts of interest and different organisational cultures (Kowalkowski et al., 2017). The development, sale, and deployment of such smart solutions require the redesign of different platform-based business models (Tian et al., 2022), the adaptation of the hybrid portfolio of all value-added products and services (Boßmann et al., 2024), and the reconfiguration of organisational processes, structures, assets and routines (Töytäri et al., 2018). The effective constitution of a PSSS, therefore, requires the overcoming of barriers, both mental and capacity (Töytäri et al., 2018), and despite the rich literature on digital servitization, the development and incorporation of software into manufacturing smart solution offerings counts a restricted number of dedicated studies, necessitating further specialised research. Therefore, this research uses case-based research to further our knowledge on this topic.

3. RESEARCH METHODOLOGY

This study adopts theory-building empirical research, that is suitable for early-stage problems. It combines a literature review (Moher et al., 2015) with a single, in-depth case-based research (Voss, 2010). To retrieve all

works relevant to our study, we used the following keywords and search strategy: ("servitization" OR "product-service system") AND ("software" OR "platform"), integrating with snowballing and cross-references the papers that were considered relevant to our research. Based on the existing literature, we identified several dimensions of investigation relating to the conflicts and tensions between servitization and the development of software and digital products. To investigate these aspects in more detail, we conducted interviews with a manager of a large industrial company, purposively selected among those that have developed both smart/digital services and software offers. The case company, whose name and financial data are kept confidential, is a leading manufacturer that provides a broad array of equipment, technologies, services, software and turnkey solutions for Energy and Oil & Gas applications. Approximately, half of revenues originate from the sale of equipment such as gas and steam turbines, turboexpanders, compressors and power generators. The other half comes from the sale of basic (spare parts and fix & repair), intermediate (multi-year maintenance contract), and digitally enabled advanced services (long-term service agreements with given targets of equipment uptime). Recently, the company started to invest resources to develop and grow an independent software business, in response to the emerging demand for intelligent operations and artificial intelligence. In 2023, they launched several digital solutions across their portfolio for existing customers, and they set up a roadmap of investments for acquiring and integrating digital partners and solutions in their organisation and business.

4. FINDINGS

As said, digital platforms within PSSs are revolutionising the industry, offering enhanced capabilities for customisation, remote service delivery and predictive maintenance (Kohtamäki et al., 2021); indeed, they become so sophisticated to allow suppliers to include software and digital products in their smart solutions offerings even sold as stand-alone businesses (Boßmann et al., 2024). However, several challenges may arise when manufacturers integrate platform software into their established digital service structures (Huikkola et al., 2020), necessitating a redefinition of the boundaries, business models and value proposition of their portfolio, which is now more hybrid than ever before (Kowalkowski et al., 2017).

The case study showed that the company in focus is devoting a lot of investment in the design, development, and distribution of digital products. After all the efforts spent on riding digital servitization, and thus building smart solutions around their core business of equipment through advanced and platform-based digital services, they are now aiming to transform their business model again by also providing stand-alone software through software-as-a-service models. This strategic transformation is expected to increase customer satisfaction, market attractiveness and value. Several acquisitions and partnerships with software firms are also used to develop digital capabilities and infuse the DNA of a full-fledged digital company into the backbone of a century-old industrial manufacturer. However, this came with some organisational tensions. The interviews with the manager show that the sales of such solutions cause internal disequilibrium, which is mainly related to the division of sales and profits of the three different components of the PSS offering. One interviewee refers to this tension as a 'triangle dilemma', depicted in Figure 1.

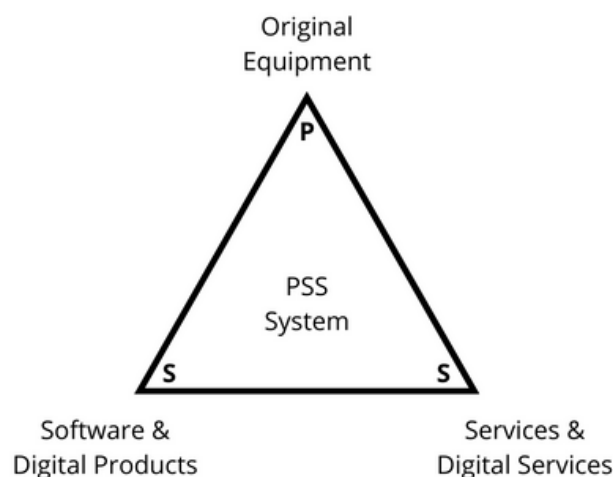


Figure 1- The PSSS 'Triangle Dilemma'.

These tensions seem to be very similar to those long ago caused by the first strategic transformation of manufacturing companies, which starting to realise the opportunities and advantages of servitization, and to approach the related changes in business models, had to face frictions between product and service business units. The biggest issue lies between the boundaries of platform-based services and platform-based digital products. The main challenges that emerged from the case study due to this hybrid portfolio can be summarised in the following interrogatives, which of course need further investigation:

- 1) For an original equipment manufacturer, is a stand-alone software/independent digital products business viable? In this case, what are the synergies with the traditional and digitally enabled product- and service-based business?

The case is making relevant efforts to develop its offering of digital products. This “OEM going digital” program is also communicated to financial investors and shareholders, as the core of the strategic transformations that are expected in the long term. There are however doubts about the actual pay-off of these investments, as the impact of this move, i.e. from back-end platforms to stand-alone digital products, is rather unclear.

- 2) Among the different types of stand-alone software that OEMs could develop and sell to the customers of their equipment, such as Enterprise Asset Management (EAM), Product Life-cycle Management (PLM), Asset Performance Management (APM), ERP (Enterprise Resource Planning) and others, which are the most promising? What kind of digital capabilities and products by the OEM are of interest to its business customers?

The case industry mostly focused on developing a software platform for managing and optimising the performance of industrial assets and processes, and for the related reduction of carbon emissions, representing integrated suites of all their most valuable digital services; but they are hesitant about the value propositions that should satisfy these digital products and thus in which market segments to market them, also because they vary according to their customers application sectors.

- 3) Is it more convenient to separate or integrate the different business unit organisations?

Currently, the studied company has several P&L units for each of the different components of the PSSS portfolio; but the respondents claimed to have strong doubts as to the best solution, and that a top leadership would be required to act as a superior entity and manage the different businesses.

- 4) What overlaps and tensions are created between the different offers within a Product-Service-Software System?

Based on the interviews, it seems that the primary challenge lies in achieving the balance between the various component units and their respective business models. Each unit aims to fully enhance its value proposition while managing the potential risk of internal cannibalisation.

Further research is essential to understand how to arrange and draw up clear and defined relationships between the different offerings and the company's core business, considering also that these vary according to the industry in focus, the different products in the supplier catalogue, and the specific applications of each customer.

The case company is motivated to ride this other innovation in the business model of digital servitization, and thus develop separate digital product businesses. However, the path to selling PSSS is still unclear, as are the internal tensions that may arise and the strategies to mitigate them. As reflected in the interviews, careful planning of a hybrid portfolio is crucial, thus the determination of the necessary elements for the realisation of the targeted value propositions, and the identification of the relevant characteristics for the description and structuring of the portfolio. For this, the study of lead users and target customers, and their needs and usage habits could be a must-have. It is important to identify the products and services with the highest added-value potential, to establish the relationships between all the different elements of the solution, and to determine the overall characteristics of the portfolio by gradually assessing the conformity between the different objectives of the specific packages. The innovation processes of the different elements (products, services, and software) should be structured ad hoc but must include integrations and synchronisations, to co-align the different business units for the effective development of smart solutions, collaborating without rigidity and thus improving the performance of the enterprise. From the interviews, some key aspects crucial for achieving balance and overcoming tensions have emerged. These include the need for positioning such

software within the company's value system and target market, improvements in understanding the customer and their needs, transitioning the corporate organizational culture towards integrated smart solutions, adopting flexible and agile development models, and overcoming organizational inertia between P&L units and product lines due to separate structures and incentives for products, services, and software. The company is actively working to address these challenges, seeking to find the optimal path forward that addresses the needs with a holistic vision beyond unit boundaries.

5. THEORETICAL AND PRACTICAL CONTRIBUTIONS

The main theoretical contribution of this research is the review and classification of scientific knowledge and strategic moves related to the businesses enabled by the inclusion of digital products among the various offerings of original equipment manufacturers' portfolios. In the literature, there is little evidence of studies on this latest evolution of digital servitization, moreover, there is ambiguity and confusion on the relative main topics; terms such as 'platforms', 'software', 'smart solutions' and 'product-service-software system' are often used with different definitions and meanings. This article aims to contribute to shedding light on the topic, to a greater understanding of the issues, to provide a collection of examples of systematic approaches found in the literature, and to disseminate four research questions for future studies.

Based on a case study, we reveal the main potential internal tensions that may occur in manufacturing contexts, between digital service offerings based on established platforms (e.g. outcome-based contracts and performance-based agreements) and emerging digital product offerings (e.g. stand-alone software platforms). Finally, we show which interrogatives original equipment manufacturers should address, regarding difficulties and complexities that may arise from the move to PSSS. Findings from this research are preliminary and limited also by the single case study, thus further research is needed to investigate and identify successful practices for this move.

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