The role of digital knowledge servitization in supply chain management

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Abstract

Purpose – This paper aims to contribute to overcoming the gap existing in the supply chain literature related to digital servitization by bridging digital servitization with knowledge management and identifying the rise of digital knowledge servitization as a driver for changes in the supply chain business model towards open innovation.

Design/methodology/approach – The study follows an inductive grounded theory approach for theory building. To analyse the impact of digital knowledge servitization, in-depth interviews of managers in the main business units of the Volvo Group supply chain ecosystem were carried out.

Findings – The results show how the digital servitization process affects the supply chain business model, highlighting the central role of knowledge in the service ecosystem and the rise of the theoretical concept of digital knowledge servitization. In particular, through the Innovation Lab (Volvo Group) study, the paper contributes to bringing together the theoretical knowledge-based view of servitization with the digital servitization concept, which demonstrates the role of this combined perspective in the transformation of the supply chain; this is carried out by introducing a new business model based on open innovation in inbound and outbound processes.

Practical implications – The research offers interesting insights from a managerial perspective, as increasingly advanced and complex digital solutions require shorter times in supply chain management (SCM). Companies need to be able to quickly manage information and knowledge flows deriving from internal and

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external interactions and involvement with external actors upstream and downstream of the supply chain ecosystem. Therefore, the digital knowledge servitization of the supply chain also highlights implications for managers in terms of human resources management.

Originality/value – The novel research goal is to contribute to the supply chain literature by integrating the digital servitization with the knowledge view and analysing the impact on the inbound and outbound supply chain through the introduction of an open innovation business model.

Keywords Digital servitization, Digital supply chain ecosystem, Open innovation, Digital knowledge servitization, Supply chain management, Manufacturing

Paper type Research paper

Introduction

The increasing interconnection and digitization of physical and virtual objects are some of the most disruptive developments in contemporary times. New digital technologies are radically changing the value creation process of manufacturing companies, pushing the servitization trend further (Ostrom *et al.*, 2010; Ardolino *et al.*, 2018) and creating new business models in the process (Ostrom *et al.*, 2010; Ardolino *et al.*, 2018; Boehmer *et al.*, 2020). Several studies have shown the dominant driving role of technology in the progress of today's service world, and they defined the exploitation of information technology as a foundation of service science (Rust and Huang, 2014; Chesbrough, 2011). Although servitization originated in the management research field and digital technologies emerged in the engineering and computer science fields (Paschou *et al.*, 2020), scholars have highlighted the existence of numerous links between the two concepts (Vendrell-Herrero *et al.*, 2017; Bustinza *et al.*, 2018). Indeed, to implement the servitization process, manufacturing firms need to raise the value chain (Finne and Holmström, 2013; Martinez *et al.*, 2017) and adopt new and alternative practices and technologies (Baines *et al.*, 2009) which generate changes in strategies, processes and organization. At the same time, digital technologies can foster the servitization process by introducing "sophisticated and novel service offerings" (Grubic and Jennions, 2018; Lerch and Gotsch, 2015) and enabling new service-oriented business models (Adrodegari and Saccani, 2017). In recent years, scholars have started to jointly analyse the two concepts of servitization and digitalization, introducing the concept of digital servitization (Bustinza *et al.*, 2018; Vendrell-Herrero *et al.*, 2017) as "the development of new services and/or the improvement of existing ones through the use of digital technologies" (Paschou *et al.*, 2020, p. 284). Digital servitization implies changing the services offered towards digital and 'smart' ones (Allmendinger and Lombreglia, 2005) and shifting the organization's business models towards an ecosystem perspective where digital servitization emerges from cocreation among different network actors (Kamalaldin *et al.*, 2020). The exploitation of data and information allows the generation of knowledge and competitive advantages (Paschou *et al.*, 2020) to define new (digital) business models. Indeed, the digitization of process and organizational learning needs to be led by strategic thinking and knowledge about how to gain relevant insights from big data (Ardito *et al.*, 2019; Schniederjans *et al.*, 2020). In this regard, scholars have shown that an ambidextrous orientation based on exploration and exploitation (Cegarra-Navarro *et al.*, 2017; Del Giudice *et al.*, 2018; Kaur *et al.*, 2019; Aslam *et al.*, 2020) leads companies to capture multiple knowledge sources from various organizations and is a key source for innovation generation (Love *et al.*, 2011; Garriga *et al.*, 2013; Roper *et al.*, 2013; Wang *et al.*, 2020). Although several studies have investigated the role of service digitalization (Bustinza *et al.*, 2018; Vendrell-Herrero *et al.*, 2017; Paschou *et al.*, 2020), the topic is fragmented across a wide number of disciplines (Paschou *et al.*, 2020), and its integration with knowledge management is still under-investigated. Indeed, in recent years several studies have investigateddigital servitization focused on the value creation of servitization through digital technologies (Zancul *et al.*, 2016; Opresnik and Taisch, 2015; Wen and Zhou, 2016), on the business

perspective of digital transformation in servitization (Belvedere and Grando, 2017; Coreynen *et al.*, 2017; Vendrell-Herrero *et al.*, 2017) and on the role of servitization as a part of Industry 4.0 (Frank *et al.*, 2019). Studies on digital servitization of the supply chain are limited, and they mainly analyse the relationship between the different actors (Paschou *et al.*, 2020); therefore, based on the knowledge-based view that considers servitization as a solution proposition of a bundle of tacit and explicit knowledge components (Valtakoski, 2017), this paper aims to contribute to filling the existing literature gap by bridging the servitization and digitalization of the supply chain using the lens of knowledge management and investigating the digital servitization implications in the supply chain ecosystem. Likewise, a greater flow of knowledge improved supply chain management (SCM) efficiencies returning more effectiveness for the knowledge management in "the process of creating, sharing, using and managing knowledge and information in an organization" (Schniederjans *et al.*, 2020 p. 2), based on the processes of exploration and exploitation (Guisado-González *et al.*, 2017; Li *et al.*, 2018). Therefore, knowledge management makes a relevant contribution to supply chain management in the new era of digitization (Xue, 2014), as it provides the tools necessary to manage a large amount of data generated by operators and their customers (Olson, 2018; del Rosario Pérez-Salazar *et al.*, 2017). The analysis of the Innovation Lab (Volvo Group) and the in-depth semi-structured interviews with managers contribute to understanding the impacts of digital servitization on the inbound and outbound supply chain through the introduction of a new business model based on open innovation; moreover, and specifically, the following research question is answered:

RQ1. How does digital servitization driven by knowledge affect SCM?

The paper is organized as follows. The theoretical background emphasizes the key points of the servitization and digitalization concepts highlighting the role of digital knowledge servitization in the supply chain ecosystem. Following the grounded theory approach, an exhaustive literature review is avoided in this paper, while a limited literature review is conducted "to ensure familiarity with major themes and topics in the area of servitization" (Crowley *et al.*, 2014, p. 7). Then the grounded theory flow is presented, and the theoretical sampling is explained together with the context of the Innovation Lab at Volvo Group. The results from the in-depth interviews with the Innovation Lab and Volvo Group conglomerates' managers in the supply chain led to the theory emergence of digital knowledge servitization. Finally, a discussion, theoretical and practical implications, limitations and further research and conclusion are presented.

Literature review

Supply chain digital servitization

The term servitization was coined by Vandermerwe and Rada (1988) and it refers to a process of creating value by adding services, support and knowledge to products (Paschou *et al.*, 2020). Over the years, several studies (Wise and Baumgartner, 1999; Oliva and Kallenberg, 2003; Paschou *et al.*, 2020) have been developed to understand the application and implication of servitization as a manufacturing strategy. In this sense, industries are involved in a servitization process by changing their strategy of doing business and in particular by shifting from product-centred systems towards product-service systems (Kowalkowski *et al.*, 2017; Martinez *et al.*, 2017). By holistically approaching servitization, this paper considers servitization as an open innovation process through which an organization can create value by shifting from selling products to selling a system of products and services (Baines *et al.*, 2009). The approach to the servitization concept, as a system of interconnected and interdependent elements capable of creating added value contemporarily to processes, products and services, enhances product innovation and customer loyalty and improves the

value of existing products (Paschou *et al.*, 2020). One of the main important elements enclosed in the servitization system is technology (Rabetino *et al.*, 2018), which allows creating value in strategies and processes (Paschou *et al.*, 2020). In recent studies, scholars have focused their attention on the integration of digital technologies into the servitization concept (Grubic, 2014; Grubic and Jennions, 2018; Lerch and Gotsch, 2015; Paschou *et al.*, 2020) to increase its value proposition. The introduction of digital technologies, such as the internet of things, artificial intelligence and augmented reality (Caboni and Hagberg, 2019; Caboni and Pizzichini, 2022) in the systems' offerings completely reshapes the system of service delivery (Ardolino *et al.*, 2018; Rymaszewska *et al.*, 2017) and accordingly modifies the industry competition system (Porter and Heppelmann, 2014). In the manufacturing sector, several cases can be observed (e.g. Rolls-Royce, General Electric, Volvo Studio), whereby firms introduced digital technologies to increase the value of the offerd products and services (Candell *et al.*, 2009; Lerch and Gotsch, 2015; Kohtamäki *et al.*, 2019). In the automotive sector, for example, Rolls-Royce decided to pay a fee for the use and availability of engines instead of buying them, and by implementing an Internet of Things (IoT) system, they could monitor engine data in real time to provide maintenance (Baines and Lightfoot, 2014; Kohtamäki *et al.*, 2019). Additionally, the case of General Electric demonstrates how the support of digital tools is able to process, analyse and interpret data using remote monitoring services (Paschou *et al.*, 2020). Considering these practical examples is fundamental to studying the convergence of servitization and digitalization as a broad and unique phenomenon called digital servitization (Bustinza *et al.*, 2018; Vendrell-Herrero *et al.*, 2017) specifically applied to the supply chain. In particular, the digital servitization of the supply chain led to organizational change by reconfiguring business models (Bustinza *et al.*, 2018) and identifying several benefits to the customer, suppliers and the environment (Paschou *et al.*, 2020). Indeed, digital servitization refers to an industrial system of intelligent solutions of products, services, software and analytics (Porter and Heppelmann, 2014) that creates service offerings with the support of technology and enhances the company's competitive advantage (Opresnik and Taisch, 2015), performance and competitiveness (Lenka *et al.*, 2017). Digital servitization could improve the security of transmission data (Nybacka *et al.*, 2015) and enhance the value of customization by increasing differentiation (Allmendinger and Lombreglia, 2005) and customer satisfaction (Paschou *et al.*, 2020). On the provider side, as Paschou *et al.* (2020) stated, several benefits are ascribed to the reduction of delivery costs (Allmendinger and Lombreglia, 2005), the enhancement of competitiveness and the acquisition of new business opportunities (Kowalkowski *et al.*, 2017), in addition to improving product performance (Rakyta *et al.*, 2016) and reducing risk (Grubic and Jennions, 2018). The benefits related to the environment and society are reducing energy consumption and environmental impact by increasing the resource efficiency or extending the product's lifespan (Bressanelli *et al.*, 2018). Hence, the exploitation of digital technologies is also evident in the development of low-cost and powerful internet-connected devices (Georgakopoulos and Jayaraman, 2016). Furthermore, some studies (Lindström *et al.*, 2018) have devoted the attention to using a multipurpose IoT cloud service platform to efficiently monitor and optimize recycling processes by improving the knowledge of customers and consumer processes.

In the literature on digital servitization, several cases (Kohtamäki *et al.*, 2019) attest to the orientation of industrial companies towards the digitalization of services and knowledge-intensive manufacturing (Cenamor *et al.*, 2017; Bonfanti *et al.*, 2018) by developing new business models that combine various products, services, software and analytics (Porter and Heppelmann, 2014). However, the digital servitization process is highly complex, and most manufacturers lag in their digital aspirations (Sjödin *et al.*, 2020; Kohtamäki *et al.*, 2019). On the other hand, companies that move towards digital servitization struggle with the business model complexities that digital servitization creates; such complexities include conflicts between digital and physical service offerings, seizing new opportunities and handling with

clashes between new ecosystem partnerships and traditional supply chain relationships and specific knowledge management competencies in terms of business organization, understanding and fulfillment of customers' needs (Chen *et al.*, 2021; Scuotto *et al.*, 2022). In this scenario, it is possible to highlight companies, such as Volvo, that are rapidly moving to find more autonomous solutions in digital servitization (Parida *et al.*, 2014; Kohtamäki *et al.*, 2019; Porter and Heppelmann, 2014), but the role of knowledge in the digital servitization of inbound and outbound supply chains is still under-investigated. In this regard, considering this evolving trend the novelty of this research is based on the in-depth study of the Volvo Group supply chain which exploits the potential of knowledge in the adoption of digital servitization, presented in the following sections. In particular, digital servitization in manufacturing companies will be analysed through the lens of knowledge management (Valtakoski, 2017), based on the role of external embeddedness and innovation tension between the processes of exploration and exploitation (Dezi *et al.*, 2019; Schniederjans *et al.*, 2020). Indeed, studies on knowledge management have shown (Wang *et al.*, 2020; Dhaigude *et al.*, 2021) that both technical and relational capabilities of managers and employees are required to enable the free circulation of knowledge and to transform it into innovations (Coreynen *et al.*, 2017; Papa *et al.*, 2021) required to implement the digital servitization of the supply chain.

Methodology

An exploratory research study was conducted to analyse the impact of knowledge on the digital servitization of the supply chain. Because the purpose of the research was to understand the new phenomenon of digital knowledge servitization, the study adopted a theory-building, qualitative research design (Golicic *et al.*, 2002). The major issues that characterize servitization and pose challenges for structuring research around one or another theoretical framework are its multidimensional character, the multiple manners of servitizing, the multiple ways of measuring servitization and its impacts (Brax *et al.*, 2021). Due to the lack of agreement on the theoretical framework and approaches on servitization, a grounded theory approach can be used where theorizing is not occurring as an *a priori* event but rather emerges from the study itself. In fact, a key issue in grounded theory "is to ensure that the research is not contaminated by the existing theory and does not unintentionally shift from creating theory to testing theory" (Crowley *et al.*, 2014, p. 3).

Grounded theory flow

This paper embraces the qualitative dimension and the inductive process of grounded theory which is recognized as an appropriate method for studying emerging supply chain phenomena using a holistic approach (Randall and Mello, 2012). The grounded theory flow (Figure 1) followed in this research was useful to address behavioural dimensions at the individual and organizational level (Randall and Mello, 2012) as emerged from the Volvo Innovation lab. The grounded theory approach allows theoretical abstraction from field data obtained from individuals who are directly involved in real-life organizational settings. Because theory is grounded in the social processes among involved actors (Mello *et al.*, 2021), direct contact with them allows the researcher to better understand the impact of digital servitization on the supply chain. For this reason, the experience developed by a leading company in the manufacturing sector, such as the Innovation Lab at Volvo Group, led to the development of in-depth semi-structured interviews carried out with managers from different areas in the supply chain. The data collection is based on the triangulation logic (Yin, 2009) of three main sources of information (Handfield *et al.*, 2019), using semi-structured interviews with managers in the main business areas of the supply chain, secondary documentation,

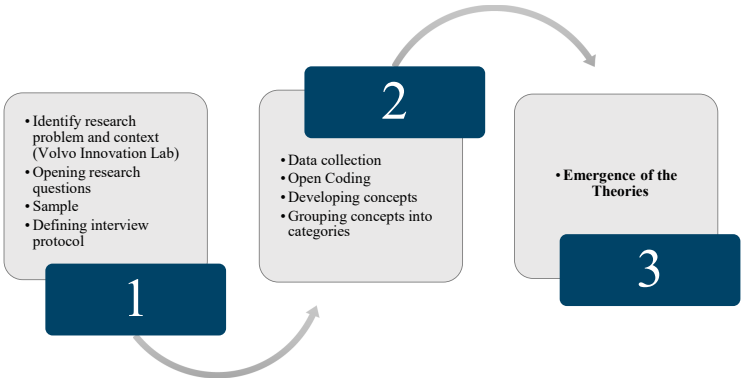


Figure 1.
Grounded theory flow

Source(s): Authors' elaboration

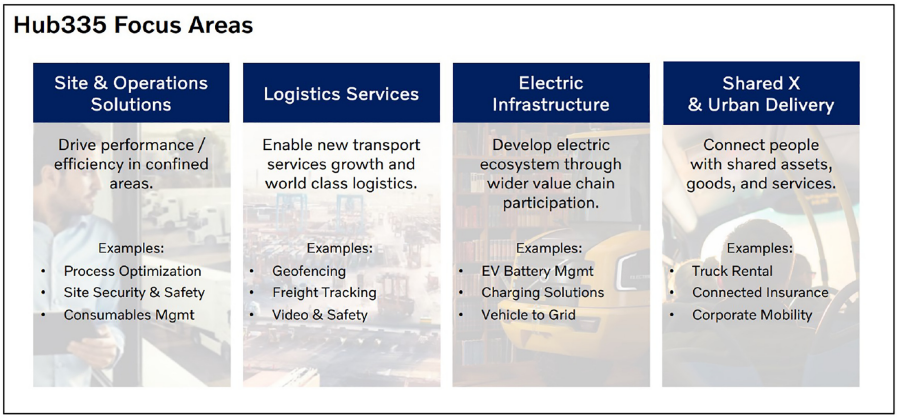
archival records, corporate documents that are both internal and available online, press articles and field visits. Data were gathered between May 2019 and February 2022, and multiple data sources avoided depending on a single informant and provided more convincing and accurate research results in terms of verification of their authenticity (Leoni, 2015). In-depth interviews were conducted to explore how the digital servitization strategy driven by knowledge changed the supply chain by introducing a business model based on open innovation.

Volvo Innovation Lab

The Volvo Group operates in the business-to-business market offering transport and infrastructure solutions, trucks, buses, construction equipment, power solutions for marine and industrial applications, financing and services. The case study analysed the Innovation Lab, which is part of Volvo Group Connected Solutions and aims at providing connected solutions to different company subsidiaries (Construction Equipment, Buses, Trucks, Penta, Autonomous Solution). The Volvo Group Connected Solutions works together with customers, partners, start-ups and the Volvo Group's different brands, combining insights across industry sectors, digital trends and customer data. The Innovation Lab has two main sites, Gothenburg (Sweden) and California (USA) and focuses on innovations, advanced analytics and visualization, digital technologies and open innovation. The role of these sites as intermediaries is threefold in the supply chain: as service solution providers in the prototype phase, as scouting for new business solutions in terms of integration through mergers and acquisitions and as venture capitalists of start-ups. Projects are conducted in a collaborative manner by multidisciplinary teams, and the ideas originate from different sources and initiatives, such as other Volvo Group business areas, workshops with the start-up community, or new insight through analysing data from connected assets (Volvo Group, 2022). The main areas of the Innovation Lab are summarized in Figure 2.

Theoretical sampling

Theoretical sampling as described by Glaser and Strauss (1967) refers to collecting data that are useful for generating theory. In fact, in this research, theoretical sampling is conducted in conjunction with coding and data analysis (Glaser and Strauss, 1967) to achieve saturating categories. Theoretical saturation was reached at 40 interviews, but 6 additional interviews were conducted to verify that the saturation was correct (Manuj and Mentzer, 2008). The key



Source(s): Volvo Group, 2022

Figure 2.
Volvo Business Lab's main business areas

informants such as Principal Innovation Managers of the Innovation Lab were asked to recommend people who had an active role in different phases of the open innovation model development in the supply chain. Because the evolution and integration of a new business model require complex interactions between multiple organizational functions, participants who had both functional and senior roles were interviewed to obtain a complete overview of the process. Participants belong to the main business areas in the supply chain ecosystem of Volvo Group, specifically, Volvo Innovation Lab managers, service-solution suppliers and Volvo group unit managers. In total, 46 interviews were conducted, and the data collection concluded when theoretical saturation was reached (Table 1).

A semi-structured interview guide was developed to administer open-ended questions on the target themes related to the following:

Department/Region participants	Supply role	N. interviews	Average time (hours/person)
Innovation Lab Volvo Group Headquarter (Gothenburg)	Senior Foresight Manager Connected Solutions	4	8 h
Volvo Group California	Director of Logistics	3	5 h
Innovation Lab Hub335 - Silicon Valley, (California)	Principal Innovation Manager	12	22 h
Volvo Construction Equipment Sales Region Americas	Volvo Connected Services and Logistics Manager	6	9 h
Volvo Autonomous solutions Headquarter (Gothenburg)	Principal Control Systems Architect	10	20 h
Volvo PentaHeadquarter (Gothenburg)	Engineer specialist Sales Manager	6	12 h
Innovation Lab Hub335 - Silicon Valley, California	Senior Innovation Manager	2	3 h
Innovation Lab Hub335 - Silicon Valley, California	Senior Service Designer	1	2 h
Volvo Group Connected Solutions	Strategic Partnership Manager	2	4 h
Innovation Lab Hub335 - Silicon Valley, California			
Total		46	85 h

Source(s): Authors' elaboration

Table 1.
Participants' information

(1) Main digital innovations that affected the company supply chain in the last 5 years;

(2) Main goals of the company in terms of solution/service provider for 2030;

(3) How the digitalization of supply chain impacts service provision - Connections between the servitization strategy and digitalization;

(4) What are the main implications in terms of knowledge management for the implementation of digital servitization in the supply chain?

(5) Knowledge acquisition practices, e.g. internal training, external recruitment, etc.

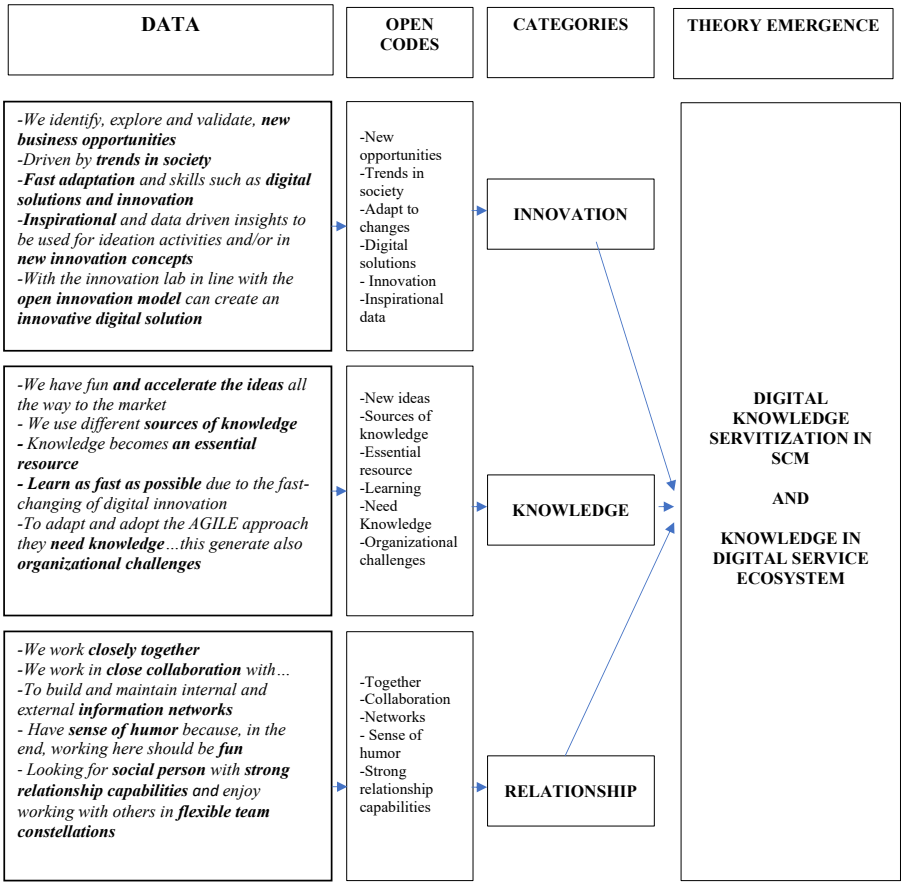
To clarify specific points and obtain further details, interviews were followed by follow-up questions, which enabled further exploration of relevant steps in the process (Jovanovic *et al.*, 2021).

The interviews were conducted in English by researchers in person and via online conference calls due to the geographical distance of the interviewees. Indeed, interviews were carried out with Volvo Group units and Innovation lab managers and specialists at both the headquarters in Gothenburg and in California (Hub335 - Silicon Valley). An interview lasted approximately between 1 and a half to 2 h and was recorded and transcribed by the researchers using a specific code. In the cases where informants did not wish to have their interviews recorded, extensive notes were taken during and after the interview (Yin, 2009). Secondary data sources such as corporate documents, annual reports, internal documents (i.e. presentations, charts, etc.), internet web pages, publications and press articles have been analysed to track the service digitalization process in the supply chain. These additional secondary data and field visits also contributed to providing the context to our informants' views, validating evidence from the interviews (Lin and Zhou, 2011) and allowing us to attain further reliability (Rowley, 2002) based on the triangulation of data collection (Yin, 2009) from different sources. Transcribed interviews, field notes and company documents were all coded to categorize, name and identify the properties and dimensions of the research. To allow theoretical concepts to emerge from the data, a process of continually questioning the information obtained and comparing the code sets was developed (Golicic *et al.*, 2002).

Open coding and categorization

The coding process was developed through the line-by-line transcription of the interview to highlight the keywords and phrases that connect the interviewer's information to the phenomenon investigated (Goulding, 2002). During the open coding process, similarities and differences were identified and are grouped together into three categories (Glaser, 2001). When the original text did not contain a key term to describe the instance of interest, an appropriate term was found to describe the instance. The coding process was developed manually by considering that this kind of coding is associated with interview research (Wagner and Fernández, 2015). This manual process aimed to analyse the data by adding codes that represented key characteristics in the textual data and categorizing the concepts in a hierarchy of categories until saturation of the sampling was reached (Figure 3). Then, the coded data were compared with data collected from the company's documents to implement the triangulation of data. Cross-reference data collected from different sources and related to different time periods allow the development of more robust theoretical concepts and strengthen the confidence and validity of the accuracy of the findings (Leoni, 2015).

The data collected from in-depth structured interviews allow developing categories carried out by following the principal quote derived from the Vice President of the Innovation Lab. From this assumption, it was possible to simultaneously identify the three theoretical pillars and



Source(s): Authors' elaboration

Figure 3.
Data overview

arrive at the grouping of the three categories: *"Innovation Lab is a place where we identify, explore and validate, new ideas and new business opportunities, driven by trends in society. We work closely together with the truck divisions and business areas in Volvo Group, as well as partners, customers and start-ups. It's a place with a large amount of energy, where we have fun and accelerate the ideas all the way to the market"*.

Innovation

The innovation category has different meanings. In particular, it refers, for example, to the capacity to adapt to changes in a complex environment and to mixing digital solutions and open innovation systems to overcome problems and crises. For example, as stated by the Senior Foresight Manager - Innovation Lab, *"The change from products to services needs fast adaptation and skills such as digital solutions and innovation. We constantly strive to generate untold value for our customers and find the next offering for Volvo Group by combining insights across industry sectors, digital trends and data from our connected fleets of vehicles and machines"*.

Innovation in a digital knowledge servitization system can also be derived from the support of several parts. Specifically, the Director of Business Innovation and foresight stated, *"Support the Innovation managers with inspirational and data-driven insights to be used for ideation activities and/or in new innovation concepts*". Additionally, the innovation value can derive from the open innovation system through which it is possible to develop specific innovative solutions. For example, the senior innovation manager specified, *"with the innovation lab in line with the open innovation model, an innovative digital solution can be created"*.

Knowledge

The use of knowledge in the development of the digital servitization system appears to be a fundamental element through which the possibility of competing in the market and consequently generating value both internally and externally can be derived (Schniederjans *et al.*, 2020). Specifically, the adoption of knowledge could be derived from several sources. As stated by the Senior Foresight Manager - Innovation Lab: *"To acquire knowledge, we use different sources. Partnerships are a new form of learning, and startups and consultancy companies provide us with knowledge. Moreover, our employees have to be fast learners to adapt to AGILE work and implement digital innovations"*. Knowledge can be considered an essential resource and is strictly connected with innovation value; it becomes fundamental to obtaining an innovative solution and adapting to changes. Specifically, the strategic partnership manager stated: *"Knowledge becomes an essential resource. As service and digital solution providers, we are also providing knowledge to Volvo Units and customers*". Moreover, *"to implement the business innovation model we need to work with Agile and learn as fast as possible due to the fast-changing digital innovation."* In the future, sharing knowledge in the optic of an open innovation system seems a critical element for adopting and adapting to the AGILE systems. From this perspective, the Principal Innovation Manager stated: *"To adapt and adopt the AGILE approach, they need knowledge that is difficult to acquire. Until now they were used to selling products, which is quite easy compared to services. This also generates organizational challenges*."

Relationship

Basically, the file rouge of digital servitization is based on the relationship between actors working for the firm. In fact, to generate innovation, knowledge and more in general value, it is necessary to activate strong relationships with all the actors in the supply chain. As stated by the Director of Business Innovation and foresight: *"We work in close collaboration with stakeholders within the Volvo Group in order to build and maintain internal and external information networks"*. However, to be able to share innovation and knowledge, it is also necessary to look for employees and collaborators with specific relationship capabilities to be able to maximize value addition to the digital knowledge servitization system. For example, as the Director of Business Innovation and foresight stated: *"We are looking for social persons with strong relationship capabilities and who enjoy working with others in flexible team constellations, who have a passion for business, technology and an interest in people"*.

Theory emergence

Digital knowledge servitization in SC

The grounded theory analysis highlights the rise of the digital knowledge servitization concept. In fact, three categories emerged, that could be considered theoretical pillars of digital knowledge servitization: innovation, knowledge and relationships. Servitization (Vandermerwe and Rada, 1988; Baines *et al.*, 2009; Baines and Lightfoot, 2014) and the more

recent concept of digital servitization (Bustinza *et al.*, 2018; Vendrell-Herrero *et al.*, 2017) could become the two theoretical underpinnings of a new concept called digital knowledge servitization which is applied to the supply chain. In the rise of *digital knowledge servitization (DKS),* knowledge is a key element for the supply chain process of companies to enable the creation, integration and transmission of digitalization (Valtakoski, 2017). In fact, the data gathered from the Volvo Innovation Lab show that the goal of the Volvo Group for 2030 to reach 50% of revenues from providing services and solutions has several implications for the supply chain, because solutions are a combination of tacit and explicit knowledge (Valtakoski, 2017) and digital components. The Innovation Lab is at the core of the supply chain, being the connector between service innovation providers and company conglomerates and contributing to the exchange of services and solutions from a knowledge perspective and facilitating this exchange. The solution is a set of knowledge components (Valtakoski, 2017), and managing the knowledge means provides the necessary tools to manage large amounts of data generated by supply chain operators and their customers (Schniederjans *et al.*, 2020). Specifically, the key elements of service offerings (Grubic and Jennions, 2018; Lerch and Gotsch, 2015) and digital technologies (Grubic and Jennions, 2018; Lerch and Gotsch, 2015; Paschou *et al.*, 2020) should be integrated into a knowledge system based on organizational learning, knowledge transfer and knowledge to increase organizational performance (Acedo *et al.*, 2006; Valtakoski, 2017). Considering the assumption that supply chain flexibility is the ability to react and adapt to environmental changes (Blome *et al.*, 2014), it became one of the primary essential conditions to compete in a complex business environment (Blome *et al.*, 2014). The introduction of the knowledge view appears fundamental to supporting this flexibility and increasing organizational ambidexterity (Acedo *et al.*, 2006; Valtakoski, 2017; Aslam *et al.*, 2020). The ambidextrous orientation guarantees flexibility (Blome *et al.*, 2014; Yu *et al.*, 2018) and the relationship between supply chain actors such as customers and suppliers (Lin and Wu, 2005) contributes to internal and external knowledge sharing and learning (Hernández-Espallardo *et al.*, 2010) enhancing the value of the supply chain. Accordingly, the knowledge management perspective, servitization and digital technologies are integrated into an open system of *digital knowledge servitization,* defined as the process of internal and external knowledge exchange that affects the entire supply chain in changing the business model and being able to sustain inbound and collaborative open innovation networks (Papa *et al.*, 2021). The system comprises several types of knowledge, for example, the knowledge embodied in physical products, intangible yet codified knowledge, such as software in information systems and tacit knowledge, such as the know-how of service experts (Wong and Karia, 2010; Valtakoski, 2017). Therefore, each product, service and technology consists of a high level of knowledge components (Sanchez and Mahoney, 1996), and the more complex the offering system, the more significant the knowledge needed.

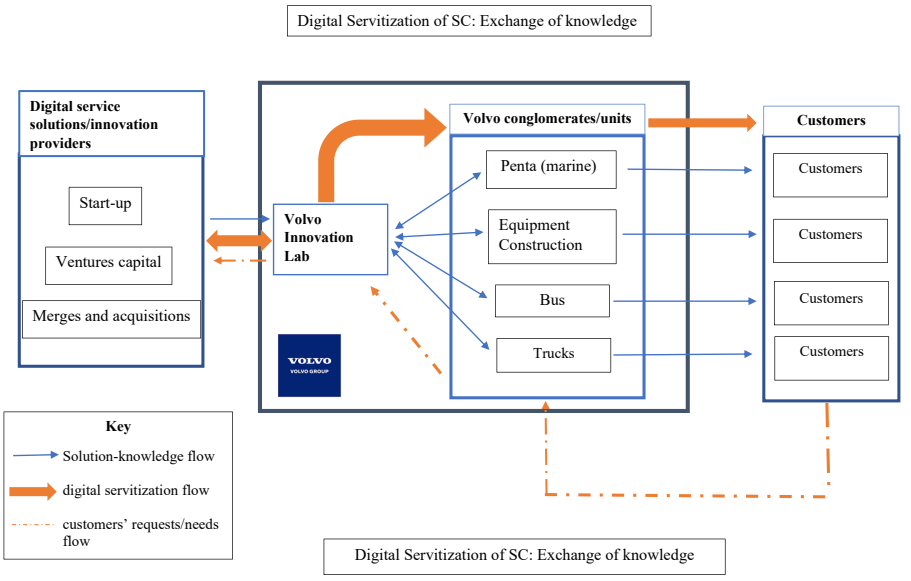
Knowledge as a driver in the digital service ecosystem

Innovations and digital technologies influence the structure of the modern supply chain, increasing its complexity. The complex and multilevel structure implies choosing integrated formats based on the economic conditions that allow mutually profitable cooperation (Shcherbakov and Silkina, 2021). These changes affect the network architecture of supply chains, how they are designed and managed and how planning and control activities occur within these chains. Therefore, the supply chain should be considered a complex system with multitier networks of upstream suppliers, downstream customers and service providers as well as their interactions and dependencies. Based on this perspective, scholars have shown how the supply chain should be considered a "service ecosystem" because competencies and skills are created at the network level and value is created for individual actors (Ketchen *et al.*,

2014; Wagner, 2021). The ecosystem perspective seems to be particularly pertinent given the increasing speed and complexity of the digital transformation of the industry (Kamalaldin *et al.*, 2020). Stakeholders are not only suppliers, customers and service providers, but "companies need to encourage supply chain collaboration with external partners in a wider ecosystem to increase efficiency, speed up innovation in the supply chain and enhance organizational agility" (Geissbauer *et al.*, 2020, p. 9). In the transition process from the dyadic transfers of ideas to the ecosystem perspective, open innovation has raised increasing interest both among practitioners and academics as directly affecting firms' utilization of existing knowledge and abilities or the development of new ones. Open innovation represents an evolution from the classical linear models of innovation, from a technology push through supply chains model (Chapman and Corso, 2005; Öberg and Alexander, 2019), to a network-centric model. In the inbound and outbound supply chain, open innovation offers more valuable information than a single type of innovation, and firms can pursue and acquire more external resources for internal research and development. This change has resulted in a shift towards the concepts of knowledge as an open flow among a series of partners and collaborators (Chesbrough, 2011). Knowledge is still the core of open innovation, but in the service ecosystem context, it is created in symbiosis with the other stakeholders rather than only for the firm's own interests (Chesbrough *et al.*, 2014; Scuotto *et al.*, 2017; Öberg and Alexander, 2019). Currently, companies need to address the accelerated rate of development and the vastly distributed knowledge, and they can no longer afford to rely on their own research. Therefore, they need to use external sources and buy or licence processes, technology, inventions and solutions. The open innovation model can influence organizational ambidexterity (Hsuan *et al.*, 2021) because it allows companies to create new or revolutionary knowledge and technologies through their current innovation activities, and at the same time, they can strengthen the extension and innovation of existing knowledge (Benner and Tushman, 2003; Gupta *et al.*, 2006) accelerating the internal innovation using inflows and outflows of knowledge (Chesbrough, 2006). However, the full adoption and adaptation to the open innovation model are not straightforward, and it remains a struggle. For this reason, the study of the Volvo Innovation Lab can contribute to the supply chain literature highlighting the integration of servitization and digitalization using the lens of knowledge management to bridge the knowledge-based view of servitization (Valtakoski, 2017) and digital servitization to understand the implications of digital servitization on the inbound and outbound supply chain with the introduction of a new business model based on open innovation. The development of value-added solutions requires effective management and sharing of knowledge flow among all stakeholders of the Volvo ecosystem (Parida *et al.*, 2014; Hullova *et al.*, 2019). Therefore, the implementation of the Innovation Lab resulted in the adoption of the open innovation business model that led to the service digitalization of the Volvo Group supply chain through digital solutions and knowledge exchange (Figure 4).

The process develops in several steps starting with the understanding of Volvo units that they do not have the internal resources in the R&D divisions in terms of knowledge, human capital and technologies to advance or overcome criticalities in a process or to respond to new customers' needs, so they reach out to the Innovation Lab. Indeed, as highlighted by the data collected, the units in Volvo's conglomerates are more oriented to a traditional business model focused on production, unlike the Innovation Lab, which, using the open innovation model, can develop an innovative digital solution in a short time. With this approach, the Innovation lab can respond to the need raised by innovation to provide integrated digital solutions quickly (Stank *et al.*, 2019). As explained by the Principal Innovation Manager, the main steps of the Innovation Lab process in the supply chain are as follows:

(1) Step – Volvo Group business units (BU) ask for Innovation Lab support on a specific project. Sometimes it is service design or digital innovation for a specific machine.



Source(s): Authors' data elaboration

Figure 4.
Volvo Innovation Lab supply chain process mapping

(2) Step – The Innovation Lab managers discuss the requests with the BU.

(3) Step – The Innovation Lab searches among partners (startups, partners' companies) for those stakeholders that have the knowledge and competencies to develop the project and solution needed.

(4) Step – One of the final customers of Volvo's BU is contacted to ask about their availability to collaborate in developing the new digital solution/service and testing it.

(5) Step – The start-up or partner company starts working together with the customer to develop the solution for the Volvo BU.

(6) Step – The Volvo unit schedules health checks with the Innovation Lab to monitor the process.

Discussion

The results from the empirical research highlighted interesting aspects concerning the evolution of the supply chains of companies operating in the manufacturing sector. Specifically, this study emphasized the vision of the interdependence between servitization, digitization and knowledge in the supply chain (Vendrell-Herrero *et al.*, 2017). The Volvo Group company has implemented a digital servitization strategy by creating a value proposition that integrates physical products, software, knowledge and services (Hsuan *et al.*, 2021). To respond to the increasingly complex and growing needs of customers and end-users, together with the increasing pressure to innovate, it is necessary to offer solutions rather than products. Digitalization increasingly favours the dematerialization of physical products and, simultaneously, the development of new digital services. As highlighted by Leoni (2015), customer needs are constantly evolving

together with technologies; consequently, the knowledge available within companies also needs to change. Therefore, a knowledge-based vision was adopted in this research to analyse aspects and challenges related to the digitization of the supply chain (Schniederjans *et al.*, 2020). The Volvo Group represents an emblematic and innovative experience from this perspective. It is possible to highlight the awareness that there is no knowledge readily available to address the challenge of innovative pressure effectively even within large companies and through leaders. Therefore, it is appropriate to change the business model by adopting the logic of open innovation to precisely use the knowledge and skills outside the organization that are useful for developing solutions that meet customer needs. The Volvo Innovation lab, therefore, strengthens the concept of open digital servitization (Hsuan *et al.*, 2021) and increases the number of studies that simultaneously address both servitization and knowledge management topics (Leoni, 2015). From this perspective, the Innovation Lab appears to be an interesting model for implementing open innovation, carrying out the functions of research and selecting providers of knowledge, skills and technologies that can be used in projects to develop new, often digital, solutions. This innovative way of providing knowledge from outside the company favours partnerships and collaborations rather than company acquisition strategies (Leoni, 2015); the crucial challenge facing the Innovation Lab is to identify the necessary knowledge to be acquired from supply chain stakeholders (Ardito *et al.*, 2020). The Innovation Lab needs to strike a balance between exploitation and exploration; therefore, the adoption of an ambidextrous orientation allows access to relevant information essential for augmenting and updating the existing knowledge (Wei *et al.*, 2011) which leads to pursuing incremental and radical innovation at the same time (Kaur *et al.*, 2019; Del Giudice *et al.*, 2018; Wang *et al.*, 2020). To integrate and coordinate the various internal and external parties involved in innovation projects by contacting and verifying the availability of end-user customers to create, develop and test innovative solutions, also represents a challenge for the Innovation Lab. The study adds a cognitive contribution to how manufacturing firms can configure the product-service-solution ecosystems, a topic that is still under-investigated (Hsuan *et al.*, 2021). Moreover, the analysis offers an example of how companies configure or reconfigure relationships with suppliers and customers to increase their ability to assimilate and apply ambidextrous knowledge (Wang *et al.*, 2020), enhancing their innovative capacity (Freije *et al.*, 2021). It is interesting to see how, for example, manufacturing company employees, start-ups, suppliers and customers share knowledge and work together to innovate. This can be considered an evolved approach to managing the supply chain that can enable manufacturing companies to create greater value by including unique elements in the offer (Vendrell-Herrero *et al.*, 2017) and by reducing supply chain risks, such as the design of products that do not meet customer needs (Lin and Zhou, 2011).

Theoretical and practical implications

The study contributes to extending the recently emerged study of the digital servitization (Vendrell-Herrero *et al.*, 2017; Bustinza *et al.*, 2018; Grubic and Jennions, 2018; Paschou *et al.*, 2020) process using the lens of knowledge management being able to consider the servitization as a solution proposition of tacit and explicit knowledge components (Valtakoski, 2017) and highlighting the emergence of the theoretical concept of *digital knowledge servitization*. The results show how in the manufacturing company digital servitization is based on the knowledge flow (Chesbrough, 2011) as well as on knowledge sharing intentions internally and externally along the supply chain (Fait *et al.*, 2021). Therefore, the company requires to develop digital service capabilities and resources to

facilitate knowledge absorption and collaboration among the different actors along the supply chain (Favoretto *et al.*, 2022). To face the need for exploitation and exploration of knowledge (Schniederjans *et al.*, 2020), the supply chain changed its model by adopting the ecosystem perspective based on open innovation as an open flow of knowledge in the inbound and outbound of the supply chain (Wagner, 2021). In managing knowledge flows and considering that digital solutions and innovation can be obsolete from the design to the delivery phase, one of the main challenges for SCM is being able to manage the time factor. The need to speed up processes implies that the acquisition and management of knowledge is crucial and affects the supply chain business model that, by adopting an ambidextrous orientation, overcomes the traditional R&D functions and adopts the open innovation model by emphasizing partnerships as forms of learning along the supply chain (Del Giudice *et al.*, 2019). Companies should also adopt an agile system (Wong and Arlbjorn, 2008), characterized by fast learners able to feed and enhance the flows of knowledge and information between the internal and external actors of the organization who are involved in developing new solutions (Geissbauer *et al.*, 2020). Another critical issue is related to human resources management. For companies, it is essential to have employees who, in addition to having adequate and constantly updated knowledge of digital technologies, should also be characterized by a particular ability to adapt to changes. Specifically, curiosity, communication and relational skills and the aptitude to work in flexible team constellations are considered important elements, in addition to the ability to manage, interpret and synthesize large amounts of data. The analysis of the findings highlighted that data are increasingly important to generate innovative ideas. In particular, the new digital technologies implemented by virtue of the open innovation model make it possible to obtain data along the supply chain to anticipate customer requests and needs.

The research offers interesting insights from a managerial perspective. First, the results of this analysis emphasize that the definition of *digital knowledge servitization,* based on an open innovation strategy, requires a strong focus on SCM and knowledge flows.

In fact, the increasingly advanced and complex digital solutions require shorter times in SCM (from the design phase to development and delivery) compared to physical products (Rakyta *et al.*, 2016); therefore, companies need to quickly manage information and knowledge flows deriving from the interaction and involvement of external actors (Chesbrough *et al.*, 2014; Öberg and Alexander, 2019) upstream and downstream of the supply chain ecosystem (Wagner, 2021). To facilitate knowledge absorption and collaborations with other actors in the digital servitization ecosystem, manufacturing companies need to develop digital service capabilities and resources. The paper offers evidence of the transformational process by which a product company changes its product-centred business model to a service-centred business model (Favoretto *et al.*, 2022) showing how a new business model based on open innovation can be integrated into a traditional manufacturing company structure (Geissbauer *et al.*, 2020). The Innovation Lab performs the functions of finding partners and coordinating with the different parties in the supply chain to exchange knowledge for the development of innovative solutions. The process also highlights implications for managers in terms of human resource management, especially in terms of the recruitment and training of employees, who, in addition to digital technology expertise, should also have skills that favour the acquisition, sharing and practical application of knowledge. Therefore, the importance of knowledge and employee engagement is confirmed together with the need for service-oriented strategy adoption (Struyf *et al.*, 2021); training programs and marketing communication actions can be useful to make such employees aware of the benefits offered to customers.

Limitations and future research

The study is based on qualitative exploratory research with in-depth interviews and field research carried out on a business leader in the manufacturing automotive sector. The case can be considered representative of manufacturing companies in the automotive sector, especially global companies, and the findings are sufficiently generalizable (Leoni, 2015). However, improving the understanding of digital knowledge servitization could benefit from extending the number of analysed companies within the same sector. An additional limitation can be represented by the sample analysed. At this stage, managers of different Volvo units and the Innovation Lab were interviewed to understand how digital servitization affected changes in the business model, but further research would be useful in terms of extending the investigation to customers and external suppliers (partners and start-ups) to understand the implications and criticalities from their perspective. Moreover, it should be considered that results are obtained from an organization that has a specific technological setup, therefore future comparative research could investigate how that can influence the competitive advantage and the value creation process. It could also be interesting to further develop the research on the introduced concept of digital knowledge servitization by studying how manufacturers develop the knowledge required both tacitly and explicitly. The Innovation Lab showed how digital servitization generated changes in the SC by introducing the open innovation model. Therefore, it is relevant to study how this new model for knowledge acquisition (i.e. mergers and acquisitions, start-up incubator) affects the relationship within the supply chain ecosystem. Specifically, further research could address the role of start-ups in inbound and outbound supply chain ecosystems (Wagner, 2021) through a multidisciplinary approach.

Conclusion

This paper contributes to research on the digitalization of the supply chain by bringing together the knowledge-based view of servitization and the digital servitization concepts into digital knowledge servitization and analysing the implications in the inbound and outbound supply chain with the introduction of a new business model based on open innovation. This study highlights how the digital servitization process of the supply chain is led by solution provision in terms of a bundle of implicit and implicit knowledge exchange internally and externally along the supply chain. From the grounded theory approach emerges how the relationships, innovation and knowledge are categories that contribute to theory emergence on digital knowledge servitization. The process affects the supply chain business model that must adopt an open innovation orientation to react with flexibility and agility. To provide solutions, companies refer to inside but also outside knowledge using collaborations with customers, partners and mergers and acquisitions. Therefore, there is a need to rethink the supply chain towards an open service ecosystem where the solution in terms of knowledge fosters digital servitization.

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