emerald PUBLISHING

The TQM J

Exploring product-service systems in the digital era: a socio-technical systems perspective

Journal:	*The TQM Journal*
Manuscript ID	TQM-11-2019-0272
Manuscript Type:	Research Paper
Keywords:	Product-Service Systems, Industry 4.0, Digitalisation, Socio-technical systems

Exploring product-service systems in the digital era: a socio-technical systems perspective

Abstract

Purpose – In the age of Industry 4.0, digital advancement is reshaping manufacturing models towards a Product-Service Systems (PSS). The drivers, readiness and challenges to move to a PSS model are not well understood and the exploitation of the digital era presents the gap of this research.

Design/methodology/approach – The research was conducted using semi-structured interviews in six manufacturers. Two forum debates were also conducted to supplement and validate the findings.

Findings – Social and economic motivations rather than environmental considerations were driving the change to PSS. Digital technologies could be an important driver, if manufacturers reached a certain PSS maturity level. A high-level of technical readiness was offset by a low-level of social investments and the strategic development of human resources. Value co-creation was a main challenge though manufacturers had the advantage of digital connectivity, which indicated new human requirements: the greater the enabling power of digital technologies, the greater the need for advanced human skills.

Practical implications – Human resource management has underpinned lean models yet the role of employees within PSS is underdeveloped despite the impact of staff in exploiting digitalisation and value co-creation. A "learning organisation" and socio-technical fit is required for the "diffusion of innovation" of PSS.

Originality/value – This research attempted to explore drivers, readiness and challenges for PSS from a socio-technical systems (STS) perspective. Three levels of PSS maturity with STS features was derived from the research providing guidance for manufacturers.

Keywords Product-Service Systems, Drivers, Readiness, Challenges, Industry 4.0, Digitalisation, Socio-technical systems

Paper type Research paper

1. Introduction

Since the 1980s, manufacturers have been changing their strategies from purely selling products towards providing integrated blends of products and services (Vandermerwe and Rada, 1988; Goedkoop *et al.*, 1999; Tukker, 2004; Baines *et al.*, 2007; Haber and Fargnoli, 2019), the latter of which are perhaps better known as Product-Service Systems (PSS) amongst academics (Li *et al.*, 2019). The shift to PSS also moves the marketing

focus from the transaction-based, mechanical views of sequential value-adding processes to relationship-based value co-creation, where different actors such as suppliers, customers and complementary partners interact with each other to co-create value (Normann and Ramirez, 1993; Vargo, Maglio and Akaka, 2008; Ng, Maull and Yip, 2009; Li and Found, 2017).

Meanwhile, in the age of Industry 4.0, rapid advances in digital technologies uniting Information and Communication Technology (ICT), Big Data, and the connectivity of Internet of Things (IoT) is reshaping the scope of manufacturing services provision at an unprecedented rate - for example the concept of "Smart connected products" (Porter and Heppelmann, 2014, 2015), "Smart Service" (Kagermann *et al.*, 2014) and "Product-as-a-Service" (Ghobakhloo, 2018). They are changing the way firms interact with their customers and the entire value chain (Porter and Heppelmann, 2015). The traditional rigid supply chain is potentially replaced with "value constellations" (Normann and Ramirez, 1993) and "value networks" (Vargo and Lusch, 2008) that are enabled through instant connectivity, interactive dialogue and a new "closeness" to the customers and/or end users (Spring and Araujo, 2009). This goes well beyond the primary principle of lean thinking (Womack and Jones, 1996) and echoes Toyota's practices of value co-creation with its partners in the multi-tier value network through the guiding principles of TPS (Rajasekera, 2010). However, although many scholars have sought to identify the drivers and challenges for manufacturers to move to PSS business models (Mont, 2002b; Isaksson, Larsson and Rönnbäck, 2009; Martinez *et al.*, 2010; Matschewsky, Kambanou and Sakao, 2018), only few studies have considered their digitalisation journey and value co-creation alongside the PSS development. There is also scarcely any research that explores manufacturers' readiness.

Though technology advances have catalysed PSS growth opportunities, technology alone cannot change the structures of business and societal acceptance of such new offerings instantly, so the expected results of transformations by manufacturers has many risks. As such, the value propositions offered by remote monitoring technologies will only be realized if customers are engaged and supportive of such solutions (Grubic and Peppard, 2016). Further, a traditional product manufacturer ("technical" focus) tends to lack the social and humanistic empathies associated with service provision (Levitt, 1983). Thus, a socio-technical systems (STS) approach that integrates both social and technical dimensions is needed to optimise the performance (Tukker and Tischner, 2006; Vezzoli *et al.*, 2015). The social dimension is defined as people, organisations, relationships, incentives and performance measures, whereas the technical dimension includes technology, innovation, knowledge, procedures and methods (Trist, 1981; Appelbaum, 1997; Geels, 2004; Baxter and Sommerville, 2011). Whist technology may define the possible, it is the integration of social and human aspects that defines the actual efficiency and effectiveness of any business. The internal fit of social and technological dimensions and external fit of the organisation in its new competitive environment requires interoperability between products, services, producers and users for success.

Industry 4.0 has set the scene for another round of competition, in which manufacturers strive to develop and apply new technologies in PSS innovations. However, researchers tend to focus on technological advances (Liao *et al.*, 2017), with limited studies conisdering both social and human aspects. For example, Ghobakhloo (2018) proposed the strategic roadmap for Industry 4.0 transition not only from the technical perspective but also from the aspects of organisation strategy, marketing, human resources and supply chain. Moreover, researchers also point out that little attention has been dedicated to connecting theory (e.g. the STS) with the issues business practitioners

are facing in the real world for robust PSS research (Kowalkowski, Gebauer and Oliva, 2017; Li *et al.*, 2019).

Thus, this research was designed to examine the current state of PSS development bound by the key research question of "What are the drivers, readiness and challenges for manufacturers to shift to PSS in the digital era, from an STS perspective?" The remainder of this paper is structured as follows. Section 2 reviews the relevant literature with particular focus on drivers, readiness and challenges. Section 3 introduces the research methodology. Section 4 presents the findings in the form of PSS drivers, readiness, and challenges, followed by the analysis in section 5. Section 6 concludes the research contributions and managerial implications.

2. Literature review

2.1 Drivers for the shift to PSS

Research evidence confirms that competitive advantage and higher financial returns are the two main intrinsic drivers for organisations to shift to PSS (Mont, 2002a; Oliva and Kallenberg, 2003; Baines and Lightfoot, 2013). External drivers include environmental regulation, corporate social responsibility (Goedkoop *et al.*, 1999; Mont, 2002b; Sakao, Sandström and Matzen, 2009; Li and Found, 2016) and developing intimate customer relationships (Oliva and Kallenberg, 2003; Gebauer, Fleisch and Friedli, 2005). Over the last decade, digital technologies have catalysed the transformation to a PSS operating model (Belvedere, Grando and Bielli, 2013; Kowalkowski, Kindström and Gebauer, 2013; Lerch and Gotsch, 2015; Martín-Peña, Díaz-Garrido and Sánchez-López, 2018). For example, the Cambridge Service Alliance found that the top five technologies that stimulate manufacturers to move to PSS are all digital technologies (Dinges *et al.*, 2015). In this research, digital technologies refer to any digital devices, infrastructure, software, processes and networks that can enable connectivity and interactivity. They include the

traditional ICT (Kowalkowski, Kindström and Gebauer, 2013; Lerch and Gotsch, 2015), as well as the emerging technologies related to Industry 4.0 such as disruptive cloud, augmented reality, big data analytics and additive manufacturing (Porter and Heppelmann, 2015; Ardolino *et al.*, 2017; Lenka, Parida and Wincent, 2017; Steenhuis and Pretorius, 2017; Ghobakhloo, 2018).

The driving role of digital technologies for PSS is also related to others including environmental sustainability and intimate customer relationships. For example, digital technologies can bring environmental benefits by: (1) simplifying mechanical components, replacing or upgrading them by software through remote control (Porter and Heppelmann, 2015); and (2) reducing transport of physical goods. For example, additive manufacturing can offer PSS providers new opportunities of producing spare parts closer to end users (Holmström and Partanen, 2014). Digital technologies also facilitate new kinds of customer intimacy such as value co-creation (Grubic and Peppard, 2016; Lenka, Parida and Wincent, 2017; Li and Found, 2017), because digital technologies enable manufacturers to build connectivity and interactivity and capture customers' latent needs and reveal emerging opportunities for future value co-creation (Porter and Heppelmann, 2015; Lenka, Parida and Wincent, 2017).

2.2 Readiness for the change

Few research papers address the contextual specificity of PSS readiness for change. Readiness for change relates to *"... beliefs, attitudes and intentions regarding the extent to which changes are needed and the organisation's capacity to successfully undertake those changes"* (Armenakis, Harris, and Mossholder 1993, p. 681). The OM literature discusses change readiness in terms of organisational structure, culture and leadership (Lehman, Greener, and Simpson 2002; Armenakis, Harris, and Mossholder 1993; Jones, Jimmieson, and Griffiths 2005; Weiner 2009), staffing and skills (Lehman, Greener and

Simpson, 2002; Weiner, 2009), and change capability (Jones, Jimmieson and Griffiths, 2005; McGuinness and Morgan, 2005) but ironically ignores technology.

From the PSS literature, Mont (2002) identified a readiness of strategic decisions, market acceptance and environmental sustainability whereas Datta and Roy (2011) perceived cultural manipulation and adapting supply chain practices as critical new organisational capabilities required. What is clear is that "readiness" is seen as a social dimension of PSS rather than a technical issue.

2.3 Challenges for the shift to PSS

The literature review identified three main themes of challenges as critical to understanding successful transformation to PSS: organisational structure and performance metrics, human resource requirements and supply network relationships.

(1) Organisational structure and performance metrics

The effective provision of PSS means manufacturers must manage an organisational and cultural "fit" of staff engaged with products and counterparts in the service operations (Oliva and Kallenberg, 2003; Martinez *et al.*, 2010; Lenka *et al.*, 2018). Manufacturers, with a strong product focus and cultural affinity to technology, must migrate employees to a services culture to release the synergies of PSS (Gebauer, Fleisch and Friedli, 2005; Sakao, Sandström and Matzen, 2009; Ulaga and Reinartz, 2011).

Many scholars have proposed a parallel organisation to handle the service offering (Oliva and Kallenberg, 2003; Gebauer, Fleisch and Friedli, 2005; Davies, Brady and Hobday, 2006), but this creates 'distance' and issues within the agility of the PSS model. First, the manufacturing issues presented include dysfunctional conflicts in the marketplace (Baveja, Gilbert and Ledingham, 2004), and competition between product and service sales teams (Kastalli, Van Looy and Neely, 2013). Second, this approach may also break the linkages between product and service lines which are "a source of lucrative

differentiation, reinforcing customer relationships or generating proprietary services value based on product understanding" (Baveja, Gilbert and Ledingham, 2004, p5). Thus, it is implicitly accepted in the literature that a harmonised synergy should be developed between product and service units.

The ability to exploit rich data and real-time feedback is challenging the traditional centralised organisation to move into distributed ones (Porter and Heppelmann, 2015). With digitalisation, functional roles overlap and blur, and the classic "contingency model" of differentiation and integration (Lawrence and Lorsch, 1967) requires more coordination. This is because "periodic handoffs no longer suffice. Intense, ongoing coordination becomes necessary across multiple functions" (Porter and Heppelmann, 2015, p. 109). Thus, communication and coordination between distributed organisations must be effective if PSS success is to be realised.

Further, organisational challenges result from conflicts between incentives and performance measures where poorly aligned metrics generate an adaptive inflexibility (Neu and Brown, 2005; Kastalli, Van Looy and Neely, 2013). For example, in product-centred organisations, incentives such as pride and recognition are directed towards advanced technical knowledge and skills, while in the service environment incentives are more related to customer-oriented relational process development (Lenka *et al.*, 2018). However, these service-oriented soft performance indicators are difficult to measure. As a result, the measurable product-oriented performance indicators continue to be used in the service business. This misalignment will result in the failure to measure the collective ability (Martinez et al., 2010) and negative behaviours that impact internal collaborations. Thus, the performance measurement and management of rewards is a significant managerial challenge for PSS (Neu and Brown, 2005).

(2) Human resource requirements

A PSS offering needs direct interactions with customers in multiple ways and in various levels which implies special skills to understand and exploit value co-creation (Ulaga and Reinartz, 2011). First, networking skills are required to access decision makers at many levels in customers' organisations to align the PSS offering effectively. Second, interactive skills are needed to offer customised bundles that are co-created with customers. Third, manufacturers must train their frontline employees to facilitate or even perform PSS sales, because field technicians often represent a key source in detecting customers' latent needs that can lead to new business opportunities.

The "skills" debates affect internal developed capabilities of existing staff (learning organisations) or externally acquired resources and consensus has not been reached on which option is better. However, PSS is likely to lead to inter- and intra-organisational mobility and secondments of personnel to work with customers will enhance these skills (Johnstone, Dainty and Wilkinson, 2009), or recruiting staff from customers' organisation into the front-office to ensure 'think like the customer and act like the customer' (Baines *et al.*, 2013). The rapid development in ICTs and requirements of integrating different systems means skill capabilities are difficult to maintain in-house and must be acquired from external resources (White, Stoughton and Feng, 1999; Baveja, Gilbert and Ledingham, 2004). As Porter and Heppelmann (2014) proposed that traditional engineering departments must now recruit talents in software, systems engineering, clouds, and big data to support organisational capability building if they are to survive in the digital era. The corporate acquisitions of digital specialist companies by industrial giants such as ABB and GE also indicate human capital development is by assimilating external resources.

(3) Supply network relationships

The shift to PSS challenges the conceptualisation of "supply chains" that focus on stable intra-firm transactional flows of physical materials in manufacturing (Hayes, 2002) and replaces it with the "supply networks" concept which emphasises multiple, dynamic relationships and dual-way flows of materials and information (Spring and Araujo, 2009).

First, the motivation to engage in networks results from the complex demands of the PSS operating model which relies upon the seamless integration of many organisational functions, many more external stakeholders (such as original equipment manufacturers, components manufacturers, system integrators, intermediators, complementary and third party service providers) in addition to deeper relationships with customers/end-users (Morelli, 2006; Xu *et al.*, 2014; Raddats *et al.*, 2017).

Second, PSS-driven customer needs are often abstract, which creates ambiguity for PSS providers in determining what they have to supply to meet customers' expectations (Tukker, 2004; Ulaga and Reinartz, 2011; Song, 2017). For example, Tuli, Kohli and Bharadwaj (2007) observed that manufacturers viewed PSS as a customised integration of goods and services. Customers, however, viewed PSS as a set of relational processes. Thus, close proximity to customer's processes (to interactively develop PSS offerings) is therefore cirtical (Batista *et al.*, 2017; Raddats *et al.*, 2017).

Third, manufacturers might be unable to master all the resources, skills, and capabilities required for the effective exploitation of PSS (Gebauer, Paiola and Saccani, 2013; Kanninen *et al.*, 2017). They need to identify other network actors to harness the complementary resources (Xing, Ness and Lin, 2013) or to develop joint capabilities (Posselt and Roth, 2017; Raddats *et al.*, 2017). Again this requires deep engagement and interactive dialogues between trading partners (Spring and Araujo, 2009). Thus, managing dynamic network relationships is a key challenge to PSS providers (Johnson

and Mena, 2008; Lockett *et al.*, 2010; Martinez *et al.*, 2010).

2.4 The socio-technical systems

The development of socio-technical systems (STS) is based on Emery and Trist's foundational study in British coal mining industry during the 1950s-1960s (Trist, 1981; Baxter and Sommerville, 2011). STS recognises the interrelatedness and joint optimisation of social elements (e.g. people and organisation) and technical elements (e.g. technology and machines) to optimise performance (Trist, 1981). The advantage of an STS focus is the co-evolution of technology and society and bridging producers with users, as users have to 'tame' new technologies to fit in their organisations and application contexts (Geels, 2004).

STS principles and practices have liberated human beings from the constraints of the traditional industrial mode of value creation and enabled value creation as a synchronic and interactive process (Ramírez 1999). This is because the technical advancement stimulated fundamental macro-social changes such as decentralisation (e.g. in organisation set-ups and collaboration patterns), democratisation (e.g. two-way communication and large-scale dialogue), and the focus on value in end use (Trist, 1981). As discussed earlier, Industry 4.0 is reshaping the scope of PSS provision, communication and collaboration patterns in networks that are enhanced by connectivity and interactivity (Porter and Heppelmann, 2015; Rymaszewska, Helo and Gunasekaran, 2017; Ghobakhloo, 2018; Zheng *et al.*, 2018). Moreover, PSS effectiveness results from interactions between different actors and technical elements during the use phase, which indicates that PSS can be viewed as a value co-creation system in the socio-technical contexts (Morelli, 2002, 2006; Ng, Maull and Yip, 2009). The STS approach, largely ignored in the current literature, is regarded as a useful means of framing the research gap.

3. Methodology design

Multiple sources of evidence (triangulation) were designed as part of the methodology to improve the validity of research findings. The main data collection phase involved semi-structured interviews of 6 purposively selected manufacturing companies, which was supplemented by 2 panel debates held in two international forums. Secondary data, including company websites and corporate publications, were employed to add supplementary evidence to verify the findings.

The purposively selected companies were drawn from the high-value manufacturing industry of machinery and equipment. According to a survey on European manufacturing industries, the top three industries that are mostly likely to become PSS role models are machinery and equipment, electrical apparatus and communication equipment (Dachs *et al.*, 2012). Also leading PSS case studies are mostly from large manufacturers that provide high-value machinery and equipment such as aircraft engines, ships, trucks, locomotives, and construction machinery (Oliva and Kallenberg, 2003; Davies, Brady and Hobday, 2006; Baines *et al.*, 2009; Johnstone, Dainty and Wilkinson, 2009). They represent a mature industry with relatively slow market growth and manufacturers have been looking for growth opportunities through services (Oliva and Kallenberg, 2003) to generate revenues over the long lifetimes of their products.

The companies were purposively selected based on a self-declaration that they had engaged in PSS implementation. The businesses covered a range of sectors including medical equipment, aerospace, automotive, shipbuilding, wind energy and trucks. They were all Multi-National Corporations (MNCs) from Western, developed countries. Access to the informants was gained by personal introductions to key people drawn from sales, operations, supply chain, engineering and services. The semi-structured interview questions were based on previous research findings in the field of PSS. They were designed to include both open questions and multiple-choice perceptual questions when

exploring the drivers, readiness and challenges. The main data was supplemented by two panel debates at international forums with representatives from 5 European MNCs. The lead author participated in all debates and held informal interviews with these representatives to explore issues further. The first panel was held during the industrial visit of the 8th PSS Conference (June 2016, Bergamo, Italy) and the second at the 9th Service Operations Management Forum (Jan. 2017, Copenhagen, Denmark) by Copenhagen Business School with a topic on 'Servitization, Interconnectivity and Big Data Analytics'. The main data sources are summarised in Table 1.

Take in Table 1. The main data source and profile of focal companies

The data collected was coded by the research team using the protocol developed by Miles, Huberman, and Saldaña (2013) and two-level descriptive codes were created: the first level code for drivers, readiness and challenges and the second level for each of them, for example competitive advantage and higher financial benefits under the first level of drivers.

4. Findings

4.1 Drivers stimulating the shift to PSS

The drivers that stimulated the shift to PSS was claimed to result from "locking in" customers for sustainable relationships and gaining competitive advantage over competitors. As the aftersales director of the truck maker (IC06) explained:

"We do it (PSS) to tie the customers through services, parts, etc., so that we get everything together and they can't go anywhere else. We get repeat business."

The respondents also claimed that the PSS shift was "pushed" by manufacturers rather than "pulled" by customers and potentially reflected an industry bias where

customers tend to be conservative and prefer to mitigate risks of large capital asset expenditures (e.g. the marine industry). As the sales director of IC04 (marine) stated: *"I think it is more driven by the supplier than driven by the customers. We are working to create more opportunities. So, we are in the driver's seat. We are more active and aggressive."*

Surprisingly, the least influential driver was environmental sustainability. Some respondents explained that providing PSS could bring environmental and societal benefits, but it was not the main driver for them to move to PSS. Technology innovation as a driver was mostly found in the companies that were already in a higher maturity level of PSS. For example, IC05 (wind equipment maker), based on its mature PSS offerings, had added new services to the PSS package for optimising the wind energy network enabled by its big data analytics and software development.

In contrast to the interviews, the panel informants revealed a significant emphasis on the impact of disruptive digital technologies on PSS and ranked highly its importance. For example, in the panel debates, PC01 (power & automation), PC03 (locomotive) and PC04 (construction machinery) all reinforced the enabling power of digital technologies as a key driver for their PSS transformation and how these initiatives had attracted significant investment in such physical resources. PC01, PC03 and PC04 had invested in Cloud technology to develop online services such as remote monitoring and preventive maintenance as part of the PSS offerings. PC04 had heavily invested in service 4.0 to connect all operating machines to the internet and then integrate weather information and onsite simulations, in order to deliver a total solution for optimising construction projects of their customers. PC01 had invested in leadership and recruited a Chief Digital Officer to lead its digital transformation reinforcing the importance of acquiring human capital for PSS. Both PC01 and PC03 expanded in Silicon Valley for digital development such

as connectivity, 3D printing and augmented reality.

4.2 Readiness for the shift to PSS

Regarding the "readiness" for the key organisational and technological factors, participants highlighted a wide range of STS factors including digital technologies, strategy, leadership, organisation setup, capability, and performance metrics. The findings showed high levels of directional readiness (strategy and leadership). All the respondents emphasised that business strategy and leadership should be first ready for the shift. For example, IC01 (medical equipment) developed a corporate strategy of moving out from a pure product provider to a solution provider. As its supply chain director explained:

"We reshaped our strategy, because hospitals are increasingly looking to develop long-term, strategic partnerships with medical equipment companies that can provide one-stop shop for hardware, software and service offerings."

IC04 also established its vision of "Smart Port" with a strategy of expanding its PSS offerings from ship level to fleet level and then to the port level. To commit on the strategy, a senior executive was appointed to take the lead of execution in each company to deliver the vision. In terms of organisation setup, the findings indicated that all the companies built separate service divisions to develop the PSS offerings. However, they adopted different types of coordination mechanisms. For example, in IC03 (aerospace) and IC04 (marine), product sales were the main contacts for PSS offerings, and they involved service colleagues based on needs. PC03 (locomotive) established a single front office (e.g. for turnkey projects) to deal with solutions. However, in IC02 (automotive), IC06 (truck) and PC04 (construction machinery), the organisations were more complex for managing PSS offering, because they separated product sales, service sales and parts sales and sometimes they competed with each other, which degraded their readiness of

offering PSS. As the aftersales director in IC06 explained:

"It is sometimes silo thinking. Truck sales just want to sell trucks, and parts sales just want to sell parts."

Generally, the firms reported low readiness levels in establishing appropriate performance measurement to incentivise customer facing units including sales and services to sell PSS packages rather than separate selling of products and services. PC05 stated that service technicians were not well-paid in some countries despite of the hard work in the fields and their efforts in identifying new PSS opportunities, which resulted in higher turnover rate. However, IC06 was an outlier with a good performance measurement system where truck sales were measured by both the amount of trucks sold and service contracts signed, and services were mainly measured by first-time fix rate. Capacity readiness referred to staffing and skills development, which for most firms was rated at the lower level. This low-level readiness was further evidenced by respondents as challenges (see next subsection).

Almost all companies claimed that they were ready to embrace digital technologies (except for additive manufacturing) to facilitate their PSS offerings, with some advanced manufacturers aiming for the broad concepts such as "Smart Factory" (PC01), "Smart City" (IC05, IC06 and PC03) and "Smart Port" (IC04). They achieved this digital readiness through inhouse development (e.g. IC03, IC04, IC05, PC01, PC03 and PC04), and/or acquisitions (IC04, PC01 and PC03) or outsourcing (IC06). When asked about the reasons of the low-level readiness in additive manufacturing (3D printing), most respondents expressed their worries of intellectual property (IP) issues, especially when it came to value co-creation.

4.3 Challenges for the shift to PSS

The major challenges reported by the respondents include mindset change, value co-creation, supply network management, internal synergy, staffing & skills, incentives & performance measurement and lifecycle solution/process. Most of these challenges are related to the social dimension and changing mindset involves a cultural revolution (of unlearning as well as learning) rather than a simple evolution. As the following quotes indicate:

"I think the challenge we got is to move from the product-centric and silo-thinking to the customer-centric and systems thinking." – Service director in IC04

"Changing employees' mindset is a challenge, esp. for big international companies. An educational program is needed for the shift… You have to hire the right people to make the revolutional change." – Corporate researcher in PC01

Most participants considered value co-creation with partners (particularly customers) as another major challenge despite of technology investments and good awareness of PSS. They show a fear that customer orientation and collaborative value co-creation cannot, at present, be realised in the absence of a designed supporting social-technical systems. However, one best practice was observed in IC06 (truck). It developed a telematic system that engaged drivers for better driving behaviour through driver training and coaching courses and real-time interactions with its diagnostics people, so that customers could save fuels and reduce accident risks. To realise the value co-creation, customers also established bonus schemes to incentivise drivers, for example, based on the amount of fuel saving.

Following value co-creation, supply network management was viewed as a third key challenge. This can be understood from the following quotes:

"The challenge is that you have to consider what is the best model for distribution and integrate the supply network to provide both products and services." – Supply chain director in IC01

"The resources and knowledge required for PSS delivery are scattered among different network actors. It is difficult to integrate them into a common platform." – Project manager in IC05

Several companies including IC04, IC06, PC01 and PC02 reported a challenge of internal synergy and staffing & skills:

"We also need some groups of integration experts. Their thinking is the whole company." – Service director in IC04

"The group likes the business separated, so we try to do our own to make our margins. We don't look across the company …in terms of skills, as the truck evolves, it is getting more complicated with electrical parts and software, so the digital skill levels also rise." – Sales director in IC06

Most companies developed the necessary skills and expertise internally or using consultants to train their employees as a form of human capital investment. Harnessing internal skills (explicit and tacit knowledge) supports the addition of service excellence added to existing product knowledge and influences "organisational setup". Structurally, collaboration and teamwork underpinned all companies but, of critical and unresolved debates between the panel groups were the incentives & performance measurement and whether a centralised, decentralised or "hub and spoke" model should be operated. Such debates may reflect the inability to create performance measures and the response time needed to compete in future marketplaces.

Lastly, manufacturers were meeting a challenge of developing life-cycle solutions and processes covering pre-sale, sale, aftersales and disposal of product activities. Almost

all the case companies claimed that they provided life-cycle solutions, but deeper questions on how they managed the disposal of products for recycling, reuse, exchange or buy-back found a fragmented approach and poor systematisation.

5. Analysis

5.1 Drivers stimulating the shift to PSS

Most of the drivers for the shift to PSS are consistent with the literature. For example, intimate customer relationship was ranked as the highest driver. This supports the argument that manufacturers are shifting to the relationship-based thinking (Oliva and Kallenberg, 2003; Ulaga and Eggert, 2006), for which manufacturers have been developing/applying digital technologies to enhance connectivity and interactivity for closer relationships (Prahalad and Ramaswamy, 2004).

However, the driver of digital innovation was mostly applied by companies that were already in advanced stages of PSS. Thus, the finding indicated that digital technologies could be an important driver only when manufacturers achieved a certain level of maturity in PSS. This is a new finding for the extant literature, where digital technology is only considered as an important driver without considering the PSS maturity levels. Further, the findings showed that environmental sustainability was considered as the last driver, which surprisingly indicated that industry practitioners viewed PSS differently from the academia. This might indicate that practitioners were not aware of integrating the technology advancement with their social and environmental considerations to establish a real STS thinking.

5.2 Readiness for the shift

Most of the firms claimed that they were ready in terms of strategy, leadership,

organisation setup and digital technologies. A fully coherent and strategy-led model of PSS implementation certainly helped to ensure leadership commitment and clear roadmap. A shared understanding and communication for internal synchronicity was also important to deploy the strategy (Durugbo, 2013).

The low-level readiness in performance measurement and capacity development, which could be the "Achilles' heel" for them to become harmonised, advanced PSS providers. Unreadiness in performance measurement was mostly linked with the organisation setup: separated product and service units resulted in separate KPIs and conflicted motivations (Kastalli, Van Looy and Neely, 2013). This paradox between the "claimed readiness" in organisation setup and unreadiness in performance measurement reflected the immature "systems thinking". As half of the manufacturers had no plans at all to align the performance metrics with the new PSS business model, this opens a new and interesting context for such research.

The findings also showed that only limited cases integrated the social readiness and technical readiness together to enhance the systems effect. For example, in the case of the truck maker (IC06), in order to encourage dealers to sell a PSS, first, they made technical improvements to integrate different quotation systems (e.g. for truck sales, parts sales and service sales) into one quotation system; second, dealers were provided a reward scheme, where sales people were incentivised to sell a package rather than only selling a truck. Further, new relationships with external collaborators will also take time to embed and, without a set of performance measures, it is unclear as to how meaningful progress towards any customer-centric strategy (e.g. value co-creation) will be established. The low-level readiness in capacity echoes the findings in challenges, which will be discussed in the following subsection.

5.3 Challenges for the shift

The findings showed that organisational structure was not considered as a top challenge for companies, which is contrary to the findings of Oliva and Kallenberg (2003) and Baines et al. (2009). The data available does not support a good explanation of this conflict, which requires further study. Value co-creation as a top challenge is not found in the literature, which adds new knowledge to understanding the shift to PSS. This is linked with the driver of enhancing customer relationships: although manufacturers had the motivation to develop enhanced, interactive customer relationships, and the "hard" digital technologies were available for them to use, they still found it difficult to establish the appropriate "soft" social dialogue and engagement to cope with the new way of collaboration.

The finding on developing internal talents is also not in line with the literature that supports an external recruitment or acquisition strategy (White, Stoughton and Feng, 1999; Baveja, Gilbert and Ledingham, 2004; Porter and Heppelmann, 2015). The adaptive capabilities of existing staff were being enhanced with new skills. Such an approach presented PSS as unthreatening to staff and avoided the excessive costs of recruitment, which led to a learning organisation (Senge, 2006). Despite the incremental nature of company adaptation, the businesses were maturing themselves for new operating models. Thus, three levels of PSS maturity were identified in terms of the STS aspect (see table 2). In short, 10% of cases were aware but inactive beyond a formalised strategy, 70% were techno-centrically investing and 20% were making meaningful progress towards an integrated STS.

Take in Table 2. Three levels of PSS maturity

The drivers, readiness and challenges for PSS from the STS perspective are summarised in Table 3.

Take in Table 3. The drivers, readiness and challenges for PSS from the STS perspective

6. Conclusion, managerial implications and research limitations

This research has, in a newly emerging operations management subject area, explored the drivers, readiness and challenges of PSS from a socio-technical systems perspective. This forms the key contributions of this research. The findings support that there is no harmony between the social and technical dimensions of business. The social dimension lags the intention to change to PSS and this will present a significant inhibitor to progress as learning curves are steep (even where product knowledge is high).

First, the research indicated that the top drivers for manufacturers to shift to PSS were highly related to the social motivations (e.g. relationships), while environmental motivation was not on the agenda for the majority, because most manufacturers viewed environmental benefits as a "by-product". This also explains why they had challenges to develop a real life-cycle solution. Digital technologies can be an important driver, if manufacturers reach a certain maturity level of PSS. Indeed, digital technologies can also bring in many environmental benefits, which will enhance manufacturers' environmental motivation. The question is that most manufacturers are not aware of this effect and do not embrace it from an STS perspective.

Second, the high-level readiness in the technical dimension and lower level in the social dimension (e.g. performance measurement and capability development) indicated that successful PSS development required manufacturers to consider the socio-technical fit – a system effect. An interesting observation was that manufacturers with higher readiness in digital technologies and embracing the broad concepts of "Smart Factory", "Smart City", and "Smart Port" were more likely to be in a higher level of STS. This might be because these concepts themselves represented true socio-technical systems, which drove manufacturers to have more considerations in integrating the social

dimension with the technical dimension. For example, the social perspective on intellectual property (IP) protection should be also considered in additive manufacturing, as it will impact value co-creation in terms of product and service innovations.

Third, the findings revealed the new kind of collaboration "value co-creation" as a main challenge. This also reflects the low level of STS development, because the ability of co-creating value depends more on the social connectivity between organisations and people than the "hard" digital connectivity itself (Breidbach, Kolb and Srinivasan, 2013). Thus, promoting interactive dialogue and a new kind of collaboration relationship is reshaping the new human dimension to business – such that the greater the enabling power of technology, the greater the need for advanced human skills and interactions. This can be achieved by building a learning organisation.

The findings also revealed several managerial implications. First, manufacturers are advised to firstly develop fundamental relationships with customers (the social dimension), and then use digital technologies (the technical dimension) to enhance relationship building for value co-creation. Second, preparing and developing the social side of PSS would accelerate the technical adoption of PSS, as the "diffusion of innovation" theory (Rogers, 1995) indicated. Third, managers may wish to develop existing staff with new skills to fill in the capability requirements. Fourth, as value co-creation is emerging and challenging firms, managers are advised to focus on special skills development of the employees such as communication and social networking ability and align the incentives with appropriate performance metrics. Fifth, the shift to PSS may bring invisible forces that break down the functional silos and combine different departments, or suppliers and customers, together in new kinds of collaboration such as value co-creation. Lastly, when developing PSS, manufacturers should avoid

superficially relying on digital technologies that go far away from their core offerings and avoid the mismatch between customers' needs and what they are offering.

Several limitations were also identified in this paper for future research. First, further in-depth case studies are required, for example, to explore how to manage value co-creation and how digital technologies facilitate this process. Second, the sample size and number of interviews needs to be expanded, although this research aimed only to explore a preliminary understanding of the shift to PSS from an STS perspective. Third, future research is advised to purposely select organisations that are at high maturity level of PSS to understand how they manage the synergy between the social and technical dimensions.

7. References

Appelbaum, S. (1997) 'Socio-technical systems theory : An intervention strategy for organizational development', *Management Decision*, 35(6), pp. 452–463.

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Crespi, G. and Ruggeri, C. (2017) 'The role of digital technologies for the service transformation of industrial companies', *International Journal of Production Research*, pp. 1–19.

Armenakis, A. A., Harris, S. G. and Mossholder, K. W. (1993) 'Creating Readiness for Organizational Change', *Human Relations*, 46(6), pp. 681–703.

Baines, T., Lightfoot, H., Steve, E., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J., Angus, J., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I. and Wilson, H. (2007) 'State-of-the-art in product service-systems', *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 221(10), pp. 1543–1552.

Baines, T., Lightfoot, H., Benedettini, O. and Kay, J. (2009) 'The servitization of manufacturing: A review of literature and reflection on future challenges', *International Journal of Operations & Production Management*, 20(5), pp. 547–567.

Baines, T. and Lightfoot, H. (2013) 'Servitization of the manufacturing firm:Exploring the operations practices and technologies that deliver advanced services', *International Journal of Operations & Production Management*, 34(1), pp. 2–35.

Baines, T. S., Lightfoot, H., Smart, P. and Fletcher, S. (2013) 'Servitization of Manufacture: Exploring the deployment and skills of people critical to the delivery of advanced services', *Journal of Manufacturing Technology Management*, 24(4), pp. 637–646.

Batista, L., Davis-Poynter, S., Ng, I. and Maull, R. (2017) 'Servitization through outcome-based contract – A systems perspective from the defence industry', *International Journal of Production Economics*, 192, pp. 133–143.

Baveja, S. S., Gilbert, J. and Ledingham, D. (2004) 'From Products to Services: Why It's Not So Simple.', *Harvard Management Update*, 9(4), pp. 3–5.

Baxter, G. and Sommerville, I. (2011) 'Socio-technical systems: From design methods to systems engineering', *Interacting with Computers*, 23, pp. 4–17.

Belvedere, V., Grando, A. and Bielli, P. (2013) 'A quantitative investigation of the role of information and communication technologies in the implementation of a product-service system', *International Journal of Production Research*, 51(2), pp. 410–426.

Breidbach, C. F., Kolb, D. G. and Srinivasan, A. (2013) 'Connectivity in Service Systems: Does Technology-Enablement Impact the Ability of a Service System to Co-Create Value?', *Journal of Service Research*, 16(3), pp. 428–441.

Dachs, B., Biege, S., Borowiecki, M., Lay, G., Jäger, A. and Schartinger, D. (2012) *The Servitization of European Manufacturing Industries*, *AIT Austrian Institute of Technology, Fraunhofer Institute for Systems and Innovation Research ISI*.

Datta, P. P. and Roy, R. (2011) 'Operations strategy for the effective delivery of integrated industrial product-service offerings: Two exploratory defence industry case studies', *International Journal of Operations & Production Management*, 31(5), pp. 579–603.

Davies, A., Brady, T. and Hobday, M. (2006) 'Charting a path toward integrated solutions', *MIT Sloan Management Review*, 43(7), pp. 39–48.

Dinges, V., Urmetzer, F., Martinez, V., Zaki, M. and Neely, A. (2015) *The future of servitization: Technologies that will make a difference*. Cambridge Service Alliance, University of Cambridge, UK.

Durugbo, C. (2013) 'Competitive product-service systems: lessons from a multicase study', *International Journal of Production Research*, 51(19), pp. 5671–5682.

Gebauer, H., Fleisch, E. and Friedli, T. (2005) 'Overcoming the service paradox in manufacturing companies', *European Management Journal*, 23(1), pp. 14–26.

Gebauer, H., Paiola, M. and Saccani, N. (2013) 'Characterizing service networks for moving from products to solutions', *Industrial Marketing Management*, 42(1), pp. 31–46.

Geels, F. W. (2004) 'From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory', *Research Policy*, 33(6–7), pp. 897–920.

Ghobakhloo, M. (2018) 'The future of manufacturing industry: a strategic roadmap toward Industry 4.0', *Journal of Manufacturing Technology Management*, 29(6), pp. 910–936.

Goedkoop, M., Halen, C. van, Riele, H. and Rommens, P. (1999) *Product Service systems , Ecological and Economic Basics*. Netherlands: Pi!MC–Stoorm CS–PRé Consultants.

Grubic, T. and Peppard, J. (2016) 'Servitized manufacturing firms competing through remote monitoring technology', *Journal of Manufacturing Technology Management*, 27(2), pp. 154–184.

Haber, N. and Fargnoli, M. (2019) 'Prioritizing customer requirements in a product-service system (PSS) context', *TQM Journal*, 31(2), pp. 257–273.

Hayes, R. H. (2002) 'Challenges posed to operations management by the "new economy"', *Production and Operations Management*, 11(1), pp. 21–32.

Holmström, J. and Partanen, J. (2014) 'Digital manufacturing-driven transformations of service supply chains for complex products', *Supply Chain Management: An International Journal*, 19(4), pp. 421–430.

Isaksson, O., Larsson, T. C. and Rönnbäck, A. Ö. (2009) 'Development of product-service systems : challenges and opportunities for the manufacturing firm', *Journal of Engineering Design*, 20(4), pp. 329–348.

Johnson, M. and Mena, C. (2008) 'Supply Chain Management for Servitized Products: a multi-industry case study', *International Journal of Production Economics*, 114(1), pp. 27–39.

Johnstone, S., Dainty, A. and Wilkinson, A. (2009) 'Integrating products and services through life: an aerospace experience', *International Journal of Operations & Production Management*, 29(5), pp. 520–538.

Jones, R. A., Jimmieson, N. L. and Griffiths, A. (2005) 'The impact of organizational culture and reshaping capabilities on change implementation success: The mediating role of readiness for change', *Journal of Management Studies*, pp. 361–386.

Kagermann, H., Riemensperger, F., Hoke, D., Helbig, J., Stocksmeier, D., Wahlster, W., Scheer, A.-W. and Schweer, D. (2014) *Smart Service Welt:Recommendations for the Strategic Initiative Web-based Services for Businesses*. Berlin.

Kanninen, T., Penttinen, E., Tinnilä, M. and Kaario, K. (2017) 'Exploring the dynamic capabilities required for servitization', *Business Process Management Journal*, 23(2), pp. 226–247.

Kastalli, I. V., Van Looy, B. and Neely, A. (2013) 'Steering Manufacturing Firms towards Service Business Model Innovation', *California Management Review*, 56(1), pp. 100–123.

Kowalkowski, C., Gebauer, H. and Oliva, R. (2017) 'Service growth in product firms: Past, present, and future', *Industrial Marketing Management*, 60(1), pp. 82–88.

Kowalkowski, C., Kindström, D. and Gebauer, H. (2013) 'ICT as a catalyst for service business orientation', *Journal of Business & Industrial Marketing*, 28(6), pp. 506–513.

Lawrence, P. R. and Lorsch, J. W. (1967) 'Differentiation and Integration in Complex Organizations', *Administrative Science Quarterly*, 12(1), pp. 1–47.

Lehman, W. E. K., Greener, J. M. and Simpson, D. D. (2002) 'Assessing organizational readiness for change', *Journal of Substance Abuse Treatment*, 22(4), pp. 197–209.

Lenka, S., Parida, V., Sjödin, D. R. and Wincent, J. (2018) 'Towards a multi-level servitization framework: Conceptualizing ambivalence in manufacturing firms', *International Journal of Operations & Production Management*, 38(3), pp. 810–827.

Lenka, S., Parida, V. and Wincent, J. (2017) 'Digitalization Capabilities as Enablers of Value Co-Creation in Servitizing Firms', *Psychology & Marketing*, 34(1), pp. 92–100.

Lerch, C. and Gotsch, M. (2015) 'Digitalized Product-Service Systems in Manufacturing Firms', *Research-Technology Management*, Sep-Oct., pp. 45–53.

Levitt, T. (1983) 'After the sale is over', *Harvard Business Review*, pp. 87–93.

Li, A. Q., Kumar, M., Claes, B. and Found, P. (2019) 'The state-of-the-art of the theory on Product-Service Systems', *International Journal of Production Economics*, In Press.

Li, A. Q. and Found, P. (2016) 'Lean and Green Supply Chain for the Product-Services System (PSS): The Literature Review and A Conceptual Framework', *Procedia CIRP*, pp. 162–167.

Li, A. Q. and Found, P. (2017) 'Towards Sustainability: PSS, Digital Technology and Value Co-creation', *Procedia CIRP*, 64, pp. 79–84.

Liao, Y., Deschamps, F., Loures, E. de F. R. and Ramos, L. F. P. (2017) 'Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal', *International Journal of Production Research*, pp. 3609–3629.

Lockett, H., Johnson, M., Evans, S. and Bastl, M. (2010) 'Product Service Systems and supply network relationships: an exploratory case study', *Journal of Manufacturing Technology Management*, 22(3), pp. 293–313.

Martín-Peña, M., Díaz-Garrido, E. and Sánchez-López, J. M. (2018) 'The digitalization and servitization of manufacturing: A review on digital business models', *Strategic Change*, 27(2),

pp. 91–99.

Martinez, V., Bastl, M., Kingston, J. and Evans, S. (2010) 'Challenges in transforming manufacturing organisations into product-service providers', *Journal of Manufacturing Technology Management*, 21(4), pp. 449–469.

Matschewsky, J., Kambanou, M. L. and Sakao, T. (2018) 'Designing and providing integrated product-service systems – challenges, opportunities and solutions resulting from prescriptive approaches in two industrial companies', *International Journal of Production Research*, 56(6), pp. 2150–2168.

McGuinness, T. and Morgan, R. E. (2005) 'The effect of market and learning orientation on strategy dynamics', *European Journal of Marketing*, 39(11/12), pp. 1306–1326.

Miles, M. B., Huberman, A. M. and Saldaña, J. (2013) *Qualitative Data Analysis: A Methods Sourcebook*. 3rd edn. Thousand Oaks, CA: SAGE Publications, Inc.

Mont, O. (2002a) 'Clarifying the concept of product-service system', *Journal of Cleaner Production*, 10(3), pp. 237–245.

Mont, O. (2002b) 'Drivers and barriers for shifting towards more service-oriented businesses: Analysis of the PSS field and contributions from Sweden', *The Journal of Sustainable Product Design*, 2, pp. 89–103.

Morelli, N. (2002) 'Designing Product/Service Systems: A Methodological Exploration', *Design Issues*, 18(3), pp. 3–17.

Morelli, N. (2006) 'Developing new product service systems (PSS): methodologies and operational tools', *Journal of Cleaner Production*, 14(17), pp. 1495–1501.

Neu, W. A. and Brown, S. W. (2005) 'Forming Successful Business-to-Business Services in Goods-Dominant Firms', *Journal of Service Research*, 8(1), pp. 3–17.

Ng, I. C., Maull, R. and Yip, N. (2009) 'Outcome-based Contracts as a driver for Systems thinking and Service-Dominant Logic in Service Science: Evidence from the Defence industry', *European Management Journal*, 27(6), pp. 377–387.

Normann, R. and Ramirez, R. (1993) 'From Value Chain to Value Constellation:designing Interactive Strategy', *Harvard Business Review*, pp. 65–77.

Oliva, R. and Kallenberg, R. (2003) 'Managing the transition from products to services', *International Journal of Service Industry Management*, 14(2), pp. 160–172.

Porter, M. and Heppelmann, J. (2014) 'How Smart, Connected Products Are Transforming Competition', *Harvard Business Review*, pp. 65–88.

Porter, M. and Heppelmann, J. (2015) 'How Smart, Connected Products Are Transforming Companies', *Harvard Business Review*, pp. 97–114.

Posselt, T. and Roth, A. (2017) 'Microfoundations of Organizational Competence for Servitization', *Journal of Competences, Strategy & Management*, 9, pp. 85–107.

Prahalad and Ramaswamy, V. (2004) 'Co-creation experiences: The next practice in value creation', *Journal of Interactive Marketing*, 18(3), pp. 5–14.

Raddats, C., Zolkiewski, J., Story, V. M., Burton, J., Baines, T. and Ziaee Bigdeli, A. (2017) 'Interactively developed capabilities: evidence from dyadic servitization relationships', *International Journal of Operations & Production Management*, 37(3), pp. 382–400.

Rajasekera, J. (2010) 'Toyota Type Value Co-Creation in Digital Businesses Using Social Networks: The New Paradigm', *Effective Executive*, XIII(4), pp. 22–28.

Ramírez, R. (1999) 'Value co-production: Intellectual origins and implications for practice and research', *Strategic Management Journal*, 20(1), pp. 49–65.

Rogers, E. M. (1995) *Diffusion of innovations*. 3rd edn. New York: New York Free Press.

Rymaszewska, A., Helo, P. and Gunasekaran, A. (2017) 'IoT powered servitization of manufacturing – an exploratory case study', *International Journal of Production Economics*, 192, pp. 92–105.

Sakao, T., Sandström, G. and Matzen, D. (2009) 'Framing research for service orientation of manufacturers through PSS approaches', *Journal of Manufacturing Technology Management*, 20(5), pp. 754–778.

Senge, P. M. (2006) *The fifth discipline : the art and practice of the learning organization*. 2nd edn, *Random House Business*. 2nd edn. Doubleday.

Song, W. (2017) 'Requirement management for product-service systems: Status review and future trends', *Computers in Industry*, 85, pp. 11–22.

Spring, M. and Araujo, L. (2009) 'Service, services and products: rethinking operations strategy', *International Journal of Operations & Production Management*, 29(5), pp. 444–467.

Stablein, D., Welebob, E., Johnson, E., Metzger, J., Burgess, R. and Classen, D. C. (2003) 'Understanding hospital readiness for computerized physician order entry', *Jt Comm J Qual Saf*, 29(7), pp. 336–344.

Steenhuis, H.-J. and Pretorius, L. (2017) 'The additive manufacturing innovation: a range of implications', *Journal of Manufacturing Technology Management*, 28(1), pp. 122–143.

Trist, E. (1981) *The evolution of socio-technical systems: a conceptual framework and an action*

research program. Ontario: Ontario Quality of Working Life Centre.

Tukker, A. (2004) 'Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet', *Business Strategy and the Environment*, 260, pp. 246–260.

Tukker, A. and Tischner, U. (2006) 'Product-services as a research field: past, present and future. Reflections from a decade of research', *Journal of Cleaner Production*, 14(17), pp. 1552–1556.

Tuli, K. R., Kohli, A. K. and Bharadwaj, S. G. (2007) 'Rethinking Customer Solutions: From Product Bundles to Relational Processes', *Journal of Marketing*, 71(3), pp. 1–17.

Ulaga, W. and Eggert, A. (2006) 'Relationship value and relationship quality: Broadening the nomological network of business-to-business relationships', *European Journal of Marketing*, 40(3/4), pp. 311–327.

Ulaga, W. and Reinartz, W. J. (2011) 'Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully', *Journal of Marketing*, 75(6), pp. 5–23.

Vandermerwe, S. and Rada, J. (1988) 'Servitization of Business: Adding Value by Adding Services', *European Management Journal*, 6(4), pp. 314–324.

Vargo, S. L. and Lusch, R. F. (2008) 'Service-dominant logic: Continuing the evolution', *Journal of the Academy of Marketing Science*, 36(1), pp. 1–10.

Vargo, S. L., Maglio, P. P. and Akaka, M. A. (2008) 'On value and value co-creation: A service systems and service logic perspective', *European Management Journal*, 26(3), pp. 145–152.

Vezzoli, C., Ceschin, F., Diehl, J. C. and Kohtala, C. (2015) 'New design challenges to widely implement "Sustainable Product–Service Systems"', *Journal of Cleaner Production*, 97, pp. 1–12.

Weiner, B. J. (2009) 'A theory of organizational readiness for change.', *Implementation science*, 4, p. 67.

White, A., Stoughton, M. and Feng, L. (1999) *Servicizing: The Quiet Transition to Extended Product Responsibility*. Cambridge, MA.

Womack, J. P. and Jones, D. T. (1996) *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. London: Simon & Schuster.

Xing, K., Ness, D. and Lin, F. R. (2013) 'A service innovation model for synergistic community transformation: Integrated application of systems theory and product-service systems', *Journal of Cleaner Production*, 43, pp. 93–102.

Xu, Z., Ming, X., Song, W., Li, M., He, L. and Li, X. (2014) 'Towards a new framework: Understanding and managing the supply chain for product-service systems', *Proceedings of the*

Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 288(12), pp. 1642–1652.

Zheng, P., Lin, T. J., Chen, C. H. and Xu, X. (2018) 'A systematic design approach for service innovation of smart product-service systems', *Journal of Cleaner Production*, 201, pp. 657–667.

Table 1 The main data source and profile of focal companies

Research Phase	Company Code	Industry Sector	Country	Participants' responsibility in company
Interview Respondents	IC01	Medical equipment	USA	General manager and supply chain director
	IC02	Automotive	UK	Operations manager and supply chain manager
	IC03	Aerospace	UK	Operations manager
	IC04	Marine	Finland	Sales director, operation director, and service director
	IC05	Wind energy	Denmark	Project manager and engineering manager
	IC06	Truck	UK	Sales director, aftersales director and telematics manager
Panel Discussions	PC01	Power & Automation	Switzerland	Corporate Researcher
	PC02	Ship building	Italy	Senior executive
	PC03	Locomotive	Germany	Customer service manager
	PC04	Construction machinery	Sweden	Managing director
	PC05	Heat transfer equipment	Sweden	Vice president of services

Table 2. Three levels of PSS maturity derived from the research

Business Type	Social Features	Technical features	Strategic Intent
Aware yet Inactive with PSS	Existing product structures and tactical product learning with awareness of PSS needs.	Existing production Technology and awareness of PSS impact.	Maintain business model and strategy with greater sensitivity to impact of PSS on business systems. A "reactionist" approach to PSS.
Aware and Actively Engaging PSS (Techno-centric)	Existing or modified product structures with some additional investment in ICTs.	Existing production technology with project-by-project (incremental change based on customer engagement) changes to the operations system.	Strategy in place and directed at competitive advantage using technological solutions.
Aware and Actively Engaging PSS (Socio-Technical System)	Products and services are fully integrated with the learning organisation.	Staff have good product knowledge and have been skilled in a service culture.	Fully integrated socio-technical system to support a distinct and formalised PSS business strategy aimed at competitive advantage and learning.

Table 3. The drivers, readiness and challenges for PSS from the STS perspective

Item	Social dimension	Technical dimension
Drivers	Sustaining customer relationships Competitive edge Economic benefits Marketing change Environmental sustainability	Advancement in digital technologies
Readiness	*High-level readiness:* Strategy Leadership Organisation setup *Low-level readiness:* Performance measurement Capability development	*High-level readiness:* ICT, Cloud, Big Data *Low-level readiness:* Additive manufacturing (3D printing)
Challenges	Mindset change Value co-creation Internal synergy Staffing and skills Incentives & performance measurement Supply network management	Life-cycle solution/process