Towards a Framework for Lean Operations in Product-oriented Product Service Systems

Abstract
More and more companies are beginning to move beyond manufacturing as a sole source of profit by offering integrated bundles of physical goods and services. This phenomenon has become popularly known as servitization, or the establishment of Product-Service Systems (PSSs). Additionally, since the success of the Japanese after WWII and the subsequent popularization of the term "Lean Production" in the 1990s, lean too has almost become a nirvana for the majority of producers. Lean has also found its way into service operations, yet there is an apparent lack of knowledge when it comes to combining the successes associated with lean thinking with the potential of PSSs. Therefore, in this paper, we make use of two best-in-class lean companies that are recognized for excellence in both product and service offerings in order to analyse PSS operations in light of lean thinking. As such, we adopt a multiple case study approach in order to propose a framework for lean *product-oriented* product-service systems.

Keywords: Product-service systems, Servitization, Lean production, Lean service, Lean PSS operations

1. Introduction

The current situation that manufacturing firms are facing is characterised by fierce global competition and the saturation and commoditisation of their core product markets (Gebauer, 2008; Matthyssens and Vandenbempt, 2008; Vandermerwe and Rada, 1989), with consequential negative effects on product sales and margins (Cohen *et al.*, 2006; Wise and Baumgartner, 1999). In addition, customer needs and expectations are becoming more complex and comprehensive (Gebauer *et al.*, 2008; Mathieu, 2001), often based on what a product does for the user, not on the product itself (Mont, 2002; Sawhney *et al.*, 2003; Stahel, 1997).

The combination of these factors has pushed companies to move beyond manufacturing towards the service domain (Oliva and Kallenberg, 2003; Vandermerwe and Rada, 1989; Wise and Baumgartner, 1999), and the old dichotomy between product and service has been replaced by a product-service continuum (Oliva and Kallenberg, 2003). This phenomenon, commonly termed as servitization of manufacturing, represents the evolution of companies' business models from a "pure-product" orientation towards integrated Product-Service Systems (PSSs), based on the provision of integrated bundles consisting of both physical goods and services (Resta, 2012; Meier *et al.*, 2010).

There are several reasons why PSS business models are attractive for manufacturing firms, as summarised by Mathieu (2001) and further refined by other authors (e.g. Baines *et al.*, 2007; Neely, 2008). These benefits can be grouped into three main categories: financial, strategic and marketing. Furthermore, potential environmental benefits of decoupling ownership of assets and use through the introduction of product-service combinations are often mentioned in literature (Mont, 2002).

However, besides these benefits, the actual implementation of PSS involves several challenges (Martinez *et al.*, 2010). It is not enough just to innovate what a business offers to its customers by introducing new services and solutions, but further changes in all areas of a company's business model are required, in an organic, structured and coherent fashion (Kindström, 2010). As argued by several authors (e.g. Becker *et al.*, 2010; Evans *et al.*, 2007; Gao *et al.*, 2011), different stakeholders and business units may be involved when products and services are combined, increasing the complexity of internal and external configuration. Companies must change the way they operate, since a number of interdisciplinary and cross-functional processes must be established, affecting existing organisational structures and processes. Moreover, delivering value through PSS may demand a network of external partnerships, where all but core-competences can be outsourced (Davies, 2004; Mathieu, 2001; Pawar *et al.*, 2009).

Unless the servitization strategy is designed and implemented correctly, the results can be counterproductive and even detrimental to the success of the business. This has led a number of companies to experience what is known as the "service paradox" (Gebauer *et al.*, 2005), where a growth in service fails to meet its intended objectives. In order to overcome or avoid the service paradox, companies involved in delivering service components must boost the sovereignty of their service offerings through the development of a common service awareness along the service chain, as well as scale-up service activities by adopting suitable practices and tools (Visnjic Kastalli and Van Looy, 2013) and establishing suitable means of communications to facilitate information sharing and processing (Brax, 2005).

The adoption of lean thinking could support companies in increasing the efficiency and effectiveness of their PSS design, development, management and delivery. Moreover, the deployment of the lean philosophy could enable the alignment of value-adding activities with the customer value-stream (Hines *et al.*, 2011), not only supporting enterprise knowledge transfer through exploiting the capabilities of those involved, but also increase the communication across functional boundaries (Tracey and Flinchbaugh, 2006) and finally, decentralise the decision making process, fostering a dynamic process of change to ensure a robust, flexible, adaptive and responsive enterprise (Bozdogan *et al.*, 2000).

Although the philosophy and practices associated with lean production have been around for many years (e.g. Womack and Jones, 1996; Womack *et al.*, 1990), and have been applied in a number of settings including both discrete- and process manufacturing environments (Powell *et al.*, 2009), product development (Karlsson and Åhlström, 1996b) and to some extent services (Sarkar, 2007), the combination of lean and product-service systems has not yet been explored. As argued by Chase and Erikson (1988), there is a subtle mix of organizational structures that are appropriate to a PPS provider that are different from those associated with either a more traditional product manufacture or a pure service provider.

Therefore, the purpose of this paper is to compare and contrast both the lean and PSS approaches, in order to develop a framework for lean product-service systems (Lean PSS). In particular, the work, drawn upon two case studies, aims at shading light on the question: "How can lean thinking be applied to PSS operations?"

The remainder of this paper is structured as follows. The next two sections present firstly our selected research design and the methodology employed for the research and secondly the theoretical background of the study. In chapter 4 we present our case study data, before we present the theoretical framework for Lean PSSs in Section 5. Finally, our conclusions, limitations and suggested areas for further work are presented in Section 6.

2. Research design and methodology

Since this study focuses on a how-type question about a contemporary phenomenon not yet thoroughly researched, a case-based approach was selected as the most appropriate methodology (Yin, 2009). As argued by Voss *et al.* (2002), the first vital step in designing case research is the definition of the conceptual framework. Such a framework explains, either graphically or in a narrative form, the main aspects that have to be studied (Miles and Huberman, 1994) and it helps researchers to: i) shape the initial research design, ii) measure constructs more accurately, and iii) have a firmer empirical grounding for the emergent theory (Voss *et al.*, 2002). The development of the research conceptual framework was based on literature review within operations strategy and management in the PSS field, as well as lean production and service.

Cases were selected based on carefully defined criteria. As the research sets out to investigate the application of lean in the PSS domain, firstly we identified a population of potential case companies that have a well-known history of using lean production, e.g. best-in-class lean firms (we selected best-in-class lean firms due to the theory building nature of the investigation). We then selected cases from this population based on replication logic, again due to the fact that we adopt a theory-building approach. In order to develop a framework for lean PSS operations, we aimed for literal replication (i.e. prediction of similar results). A shortlist of case companies were contacted in an attempt to gain access, and the selection procedure finally resulted in two best-in-class lean case companies.

During case studies, data were gathered in the field. The methods, instruments, procedures and general rules to be followed in carrying out the data collection were included in the case study protocol, obtained by synthesising the conceptual framework into semi-structured interviews (the protocol was first tested and refined through the use of an additional pilot case study in order to strengthen construct validity).

The onsite interviews were carried out by two of the authors in order to increase the reliability of the study, and interviewees included a number of management personnel at both of the case companies, e.g. Lean manager, Service manager, Quality manager, Logistics manager, and / or Operations manager.

Supplementary methods of data gathering were also used in order to triangulate the data obtained from the interviews, also strengthening the construct validity of our study. The other methods adopted include analysis of company documentation, as well as direct observation through tours of the facilities, which provided an opportunity to verify and clarify the data collected during the interviews.

The case studies allowed the identification, evaluation, and matching of patterns as they emerged from within-case analysis in accordance with a theory building approach (Eisenhardt, 1989; Yin, 2009), that prescribes firstly to become familiar with each case as a separate entity in order to identify case specific patterns, and then to make cross-comparison to identify common patterns. The results were finally used to build the theoretical framework related to operations strategy for lean PSS.

3. Theoretical background

This section describes current theory regarding the developments in PSS Operations strategy. In order to form a suitable lens of analysis, this section also provides an overview of the evolution of lean thinking in both the manufacturing and service contexts.

3.1. Operations strategy for Product-Service Systems (PSSs)

Even if discussions about servitization and its impacts on how a business operates have attracted increasing consideration among scholars and practitioners, little attention is dedicated to understanding how organisations and processes for traditional manufacturing should be rethought to enable the efficient and effective design, development, management and delivery of PSS (Oliva and Kallenberg, 2003). In particular there is a lack of studies which have examined the implications of servitization on operations management and the revisiting of traditional operations management tools, techniques and frameworks (Wilkinson *et al.*, 2009) with a new PSS perspective.

A few exceptions can be found in literature. The first paper by Johannsen and Leist (2009) explores the possible application of a six sigma improvement program in the context of integrated solution, with a focus on the "Define" phase. Olhager and Johansson (2012) analyse long term capacity management decisions for integrated manufacturing and service operations. The proposed framework is based on long-term capacity management for manufacturing operations (chase/level and lead/track/lag decisions), afterwards adapted to service operations (front/back office operations). Datta and Roy (2011) discuss key operations strategy dimensions and how they contribute to the successful delivery of PSSs through the investigation of two case companies providing engineering service contracts. The key elements of operations strategy identified by the authors are: contract definition, operations strategy of the service provider, service delivery strategy and customer operations. Finally, Baines *et al.* (2009) propose a set of operations principles, structures and processes for the delivery of product-centric servitization. The characteristics of the framework are based on an analysis and synthesis of literature related to servitization and PSS, as well as to production and service operations, supplemented with data from an exploratory case study. The framework is built on three principal categories (scope, characteristics of value and characteristics of operations) and intends to bridge the gap between model and classifications that focus either on pure product or service operations.

While the papers from Johannsen and Leist (2009) and Olhager and Johansson (2012) are focused on specific aspects of operations management, the works presented by Datta and Roy (2011) and Baines *et al.* (2009) have a wider breath and offer a strategic perspective, providing a basis to investigate the impact of servitization on operations management. However, the two research works refer to different types of PSSs. In fact, as argued by Tukker (2004), there exist three PSS categories: i) product-oriented (where the business model is still mainly geared towards sales of products, with the addition of some extra services), ii) use-oriented (where the traditional product still plays a central role, but it stays in ownership with the provider and is made available in a different form), and iii) result-oriented (where the client and provider in principle agree on a result, and there is no pre-determined product involved). These three types can be placed along a "servitization continuum" (Oliva and Kallenberg, 2003), with an increasing level of servitization moving from product- to result-oriented PSS. Baines *et al.* (2009) propose a set of operations principles, structures and processes for the delivery of product-oriented PSSs, while Datta and Roy (2011) develop a set of operating principles and processes supporting effective delivery of result-oriented PSSs.

As an initial step of the research, we focus our investigation on product-oriented PSSs in particular, corresponding to the first level of servitization on the servitization continuum. Consequently, we adopt the framework proposed by Baines *et al.* (2009) to form a basis for our analysis, whereby we consider the "Characteristics of operations" defined in the framework to guide our investigation of lean operations in the context of product-oriented (product-centric) PSSs.

3.2. Lean production

The origins of lean thinking can be found on the shop-floors of Japanese manufacturers, particularly Toyota Motor Company and the Toyota Production System (TPS). Since the term lean production was popularized in *The Machine that Changed the World* (Womack *et al.*, 1990), many producers have begun to look at their operations in a different light.

As Womack and Jones' (1996) first lean principle, the critical starting point for lean thinking is value. As such, it is widely recognised that customer-focussed value creation is the real essence of lean production, through the systematic identification and elimination of non-value adding activities, or waste. By altering the perspective from a mere waste reduction focus to a complementary customer-value focus, a new dimension is provided in which value creation is deeply rooted and where it can be increased not only by reducing internal waste, but also by developing and adding additional features or services without incurring additional costs (Hines *et al.*, 2004). However, Williams (2010) suggests that most lean practitioners have failed to properly understand and apply the first and most important lean tenet – to truly and deeply understand what customers value, and will value. By selecting a forward looking long-term strategic view of customer value rather than a backward looking short-term tactical view on customer satisfaction, manufacturers can better understand the requirements for customer value creation. In a mass production, product-focused approach, an organisation attempts to find customers for its products by using mass marketing efforts; whilst with lean production, a customer centric approach requires products and services to be developed to fit customer requirements (Powell, 2011). We suggest that the definition of value is a critical step towards the identification and elimination of waste within the manufacturing enterprise.

Lean production focusses strongly on the reduction of seven types of waste in manufacturing operations, as identified by Ohno (1988): transportation; inventory; motion; waiting; overproduction; over-processing; and defects. These seven types of waste all represent 'Muda', which is the Japanese term for waste. However, TPS refers to a trilogy of 'Muda, Mura and Muri', where Mura refers to unevenness (of operations), and Muri denotes overburden (Bicheno and Holweg, 2009).

Therefore a lean manufacturing system must be built around a continuous-flow process supporting one-piece and just-in-time (JIT) logic. It means that at any stage of the product life-cycle, as well as any level of the supply chain, people jointly work by adopting standardized processes, and simple techniques and methodologies to ease process management, enhance production capacity, develop product quality and assure an efficient and flexible, total system.

Nevertheless lean manufacturing is as much about operational excellence as it is a strategy approach. It should be viewed more as business philosophy than a merely set of tools and techniques, where members of different organisations think and behave coherently, adopting common long-term strategies, and implementing shared information and competences (Liker, 2004). This reflects the recognition that lean transformation needs to be seen as a journey and not as a mere tactical process provided through a set of tools and techniques (Bhasin and Burcher, 2006).

We identify the fundamental elements of lean production operations in Table 1, in order to develop a conceptual research framework which we use for analysing lean in the context of product-service systems. In the following section we repeat the process in order to identify the fundamental elements of lean service operations, which we also list in Table 1.

3.3. Lean Service

Bicheno (2012) suggests that the original five lean principles – value, value stream, flow, pull and perfection (Womack and Jones, 1996) were written purely with manufacturing in mind. For example, value for a product is to do with its worth, i.e. what customers are prepared to pay for. But for service, 'value' is more complex. As product-service systems extend the focus beyond manufacturing operations, it is necessary to re-consider the lean approach, in this instance in the context of service operations.

Despite the extraordinary growth of the service sector and its pivotal role in the global economy, the level of productivity in this sector has been much lower than that of the manufacturing area. However, as the lean concept migrates from manufacturing industry, service organizations have been quick to adapt and deploy lean principles in the context of service operations. As such, Bicheno (2012) proposes five new principles for lean service: Purpose, System, Flow, Perfection, and People. Likewise, Bowen and Youngdahl (1998) also suggests that lean service can be present when certain principles could be discerned in an organization: flexibility and responsiveness, focus on individual customers, value-chain integration and disaggregation, empowerment of employees and teams, knowledge management, and networked organization.

To grasp the lean approach in a service-company context, senior managers must recognize that all organizations-manufacturing and nonmanufacturing-ultimately deliver value to a customer in the form of a product and/or service. The lean approach focuses on eliminating non-value activities from processes by applying a robust set of performance change tools, and emphasizes excellence in operations to deliver superior customer service (Allway and Corbett, 2002).

Other works within the lean service area focus primarily on lean tools and techniques, e.g. Ahlstrom (2004) and Radnor and Boaden (2008), whilst Suarez-Barraza *et al.* (2012) focus on a number of other aspects, including the classification of five specific application areas for lean service: healthcare, education, banks and financial institutions, airlines and mechanical workshops, and hotels and restaurants. Though to some extent Hutchin's (2006) account of the application of lean in the aircraft maintenance division of United Airlines represents a typical aftersales scenario (e.g. for repairs and maintenance work, United's parts are centrally located so instead of going to several different places to pull parts from multiple shelves, a mechanic can go to a single place for the parts needed for repairs), specific examples of lean in aftersales services and product-service systems are somewhat limited. We therefore identify the fundamental elements of lean services from the extant literature in order to develop a conceptual research framework for analysing lean in the context of product-service systems.

3.4. The conceptual research framework

Table 1 illustrates the conceptual research framework which underpins the research. It is based on the framework developed by Baines *et al.* (2009) for PSS operations, and has been constructed using a description of the fundamental elements that characterise lean production and lean service operations. These elements have been identified following a review of the extant lean production and lean service literatures.

Table 1 – The conceptual research framework

Unit of analysis	**PSS operations (Baines *et al.*, 2009)**	**Lean production operations**	**Lean service operations**
Characteristics of operations: structural			
Process and technology	Tend to exploit a range of technologies, throughout operations, to achieve efficiency in production and effectiveness in service delivery.	Tend to standardize processes, and use simple, tested technologies. Processes are grouped for continuous flow (Liker, 2004), and are controlled adopting visual and standardized methods and tools (Feld, 2001).	Tend to focus on the improvement of process quality (Suarez-Barraza et al., 2012) and use technology as a means of front line support rather than replacement (Bowen and Youngdahl, 1998). Tend to also use e-Services such that information technologies can be used to reduce necessary, non-value adding activities (Type 1 muda).

Capacity	Tend to experience varying demand signals at multiple customer "touch points" and so need to operate with differing levels of capacity utilisation.	Aim for level schedule based on capacity and material flow (Arnold *et al.*, 2012). Extra workers are added to the system to reduce takt-time only if full capacity is reached.	Tend to use standardisation and "product-family" grouping techniques (service/required or nature of business) to level capacity utilization (LaGanga, 2011).
Facilities	Tend to combine both centralised manufacture, but mainly focusing on product final assembly and test, along with multiple field facilities for maintenance and repair located close to market.	Tend to be large facilities with cellular flow-oriented layout. Suppliers are located nearby, or on the same site.	Certain types of services need to be produced as they are consumed. Therefore centralisation becomes impossible (Johnston and Clark, 2005). Service facilities are thus distributed and located optimally with the needs of the customer in mind.
Supply chain positioning	Tend to retain vertical integration in product manufacture and a range of closely integrated partners to deliver services.	Japanese tradition for keiretsu and zaibatsu suggest both vertical and horizontal integration (Powell, 2013). Internal lean structure replicated outside the manufacturing process in terms of lean procurement, distribution and partnership (Karlsson and Åhlström, 1996a). Long term relationship with suppliers & supplier development (Hines *et al.*, 2000).	Maintaining in house control over the highest value-added activities and off-loading other activities to specialized factories (Bowen and Youngdahl, 1998 The more geographically dispersed is the organisation, because of service inseparability, the more important is integration across the network (Åhlström, 2004).
Planning and control	Tend to focus on the optimisation of product availability.	Aim for level schedule based on capacity and material flow. Lead times are reduced significantly, so forecasts are less important (Arnold *et al.*, 2012). Pull production is consumption driven – sell one, make one. This requires reduced lot sizes and assumes negligible setup times (Powell, 2014).	Lean service is proactive and seeks to reduce waste and focus on customers rather than correcting failures (Suarez-Barraza et al., 2012).
Characteristics of operations: infrastructural			
Human resources	Tend to need workers with high levels of product knowledge and relationship development capability.	All activities are team-based and the organization is horizontally, not vertically oriented (Jones, 1990). Wherever possible, responsibility is devolved to the lowest practical level in the plant, where multi-skilled (multi-tasked) workers are trained in standardised work and problem solving. A lean culture is built by adopting routines (Kata) that are developed through continuous improvement, coaching and creating a sense of urgency (Rother, 2009).	The entire organization must embrace a commitment to change (Allway and Corbett, 2002). People are recognized as the true engine of lean (Bicheno, 2012). The negative impact of service process variation is reduced through adoption of a flexible, multi-skilled workforce, which also requires "Gemba-style" leadership.
Quality control	Tend to use product assurance methods combined with customer satisfaction assessments.	Tend to use process capability studies and statistical process control (Shah and Ward, 2007).	Tend to emphasize the prevention of "failure demand" in service operations – i.e. value adding activities can (by definition)

		Mistake proofing (Poke-yoke) and Kaizen (continuous improvement) are also widely adopted (Shingo, 1986). Develop autonomation (Jidoka), stopping machines whenever an abnormal condition is detected.	only be carried out right first time (Seddon et al., 2011).
Product/service range	Tend to have limited range combined with “bundles” of supporting services.	Products and components (as well as processes) are typically standardized. Efforts are made to reduce variation.	Services are standardised if “frequently repeatable”. Tend to identify opportunities for shifting processing volumes and service mix to reduce costs while still meeting customer expectation.
New product/service introduction	Tend to used centralised capabilities for product design, taking particular account of maintenance and repair and that complement services co-created with the customer.	Both suppliers and customers are actively involved in the new product development process (Karlsson and Åhlström, 1996b). Customer viewpoint is integrated in the product development process to support the development strategy coherently (Hines *et al.*, 2006).	Service engineers and managers work together with customers and major stakeholders when developing new services (Jun et al., 2014).
Performance measurement	Tend to use product availability, response time and customer satisfaction.	Activities are coordinated and evaluated by the flow through the team or plant, not by individual departmental targets (Jones, 1990). Lean philosophy emphasizes total system efficiency (Bicheno, 2012). An explicit prerequisite of lean is to align performance metrics with the strategy (Bhasin, 2008). KPIs are carefully selected to support Kaizen activities.	“Create flow, maintain flow, organize for flow, measure for flow” (Bicheno, 2012). Lean service providers tend to take a systems perspective, where services are more dynamic and hence require feedback, in both the positive and negative sense. Tend to create and manage a comprehensive set of front-line KPIs (Allway and Corbett, 2002).
Supplier relations	Tend to integrate internal and external supply chains into the delivery process to achieve cost effective flexibility in supply.	Require companies to work closer with suppliers in order to reduce supplier lead-times and increase supplier quality, e.g. supplier development (Simpson and Power, 2005). Long-term supplier relationships are deployed.	Tend to maintain a strong focus on supplier relations in order to achieve effective information flow (Apte and Goh, 2004).
Customer relations	Tend to have strong interaction with customers through relationships based on product availability and performance.	Primary focus is on customer value which requires close contact with customers. Wasteful (non-value adding) activities are systematically identified and eliminated (Hines *et al.*, 2004).	Lean services shift the focus away from "shop floor" to an approach that seeks to enhance value to customers by adding product or service features and/or removing wasteful activities. “Customer service is the key to ensuring waste reduction in lean services” (Spanbauer, 1995).

4. Case studies

The conceptual research framework was used to develop a case study protocol, which was initially tested and refined during a pilot case study (see Powell *et al.*, 2012). The protocol was then applied to two case studies in Italy: Alpha (this case study prefers to keep its identity anonymous) and Toyota Motor Italia. During each case study, the operational characteristics reported in the conceptual research framework were described and their compatibility with each of the lean production and lean service operations was evaluated using a 5-point Likert scale. The results are shown in Tables 2 & 3, and are graphically represented in Figures 1 & 2.

4.1. Alpha, Italy

Alpha is one of the world's leading technology and service suppliers to the oil and gas industry. At its headquarters in Italy, Alpha offers a large portfolio of advanced technology equipment and services for all segments of the oil and gas industry, from exploration and production to downstream. With a globally installed base of more than 20,000 units from production through transportation and processing into finished products, Alpha is one of the industry's major suppliers of turbomachinery, compressors, pumps, static equipment and metering systems. The company has 43,000 employees and in 2013 had revenue of approximately $17B.

As a company, Alpha is recognized for its best-in-class Lean Six Sigma practices. Alpha first began implementing Six Sigma in the mid-90s, and further embraced Lean operations in the early 2000s.

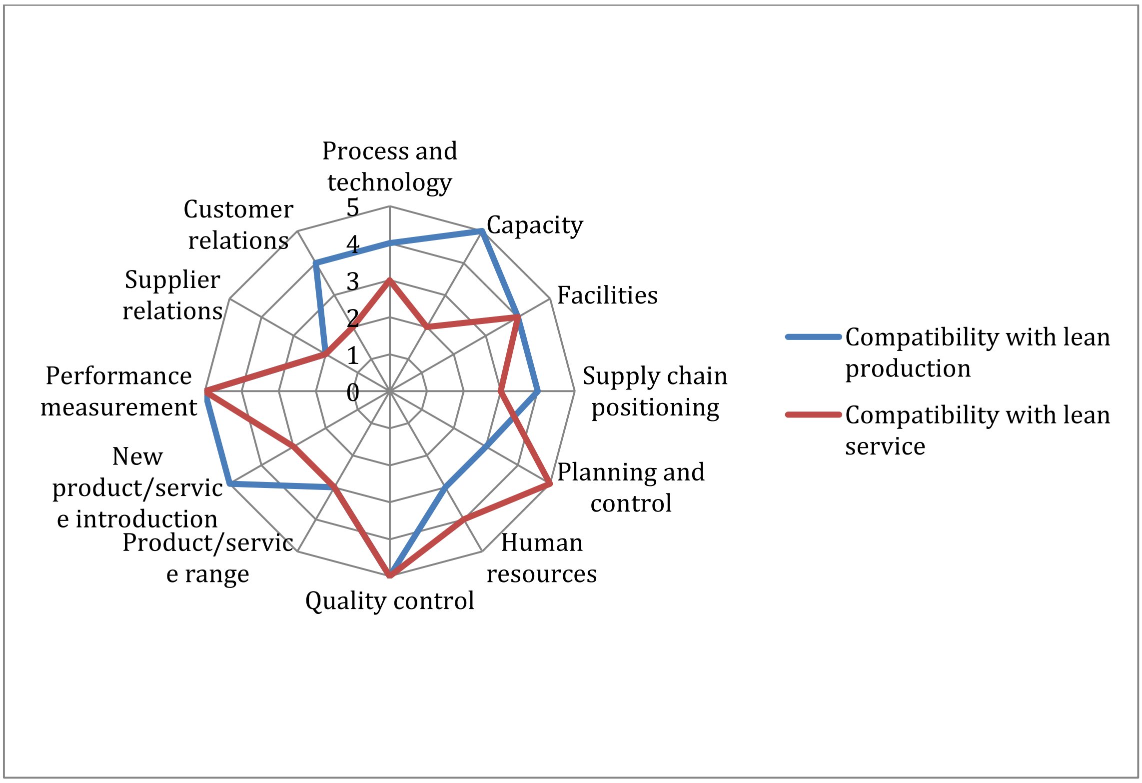
The interviews at Alpha were carried out on March 13th 2014, with two interviewers and a total of 9 interviewees. The results are shown in Table 2:

Table 2 – Case description in the perspective of lean PSS operations – Alpha

Characteristic	Alpha's PSS lean operations	Compatibility with lean production	Compatibility with lean service
Process and technology	Alpha uses standardized processes and proven technologies. Aftersales services are planned with continuous flow in mind.	●●●●○	●●○○○
Capacity	Alpha bases the planning and control of its operations on the American Production and Inventory Control Society (APICS) standard, focussing on three main building blocks: Demand (volume, mix, and location), Capability, and Infrastructure. The company has a capacity planning tool that uses a 3 year business plan to drive a 12 month operational plan.	●●●●●	●●○○○
Facilities	Alpha's service / repair facilities are setup to achieve best possible flow with limited WIP. The business strategy is focussed on localization of the service operations rather than centralization, and the main drivers of this are national oil companies (NOCs).	●●●●○	●●●●○
Supply chain positioning	Alpha manages 30% of the demand for field service engineers (FSEs) using vertically integrated suppliers. The company has worked with reducing its supplier network through increased supplier collaboration and development, for example 82% of the 2014 volume was covered by 3 main suppliers. Alpha also has a certification plan for its suppliers, in order to increase performance levels.	●●●●○	●●●○○
Planning and control	Alpha is leveraging experience from the Aviation Division in order to improve its ability to forecast and plan parts. The company has a policy for managing capital parts (e.g. turbomachinery impellers), and manages materials for service operations in advance orders using historical forecasting methods. The company has a stock replenishment policy with safety stock, as shortages can be very costly for its customers. Planning for	●●●○○	●●●●●

	shutdown repairs in the field ("outages") begins 24 months in advance using Alpha' "outage excellence process".		
Human resources	Alpha has a very comprehensive employee development strategy. The HR has defined a global field service career path, from trainee through master engineer to regional manager. There is also an emphasis on developing soft skills, as these are fundamental in the face of the customer. Alpha makes use of multi-skilling and have a competency matrix, and have this year developed a site manager training program and global operation training academy.	●●●●○	●●●●○
Quality control	Alpha is renowned for excellence in quality control through its Six Sigma program. In addition to this, Alpha have established quality control job cards and a job card library, as well as a site quality check list for its field service operations. In repair shops, operators have the authority to raise a "red card" in order to stop work for quality issues.	●●●●●	●●●●●
Product/service range	Alpha offers customized equipment and service solutions (composed of standard modules) to the oil & gas industry. Typical products are compressors and pumps, and the service portfolio includes contractual and maintenance services, and upgrade and industrial services.	●●○○○	●●●○○
New product/service introduction	Alpha has a tollgate new product introduction (NPI) process that is owned by the product leadership department. The engineering function is a key partner in this process. The company's service model is developed concurrently with the product development process, which is particularly important in light of radical product development.	●●●●●	●●●○○
Performance measurement	Alpha has a comprehensive performance measurement and management system, and develops KPIs that are important to its customers. Metrics are defined to evaluate internal performance in quality and health, safety, and environment (HSE), as well as the performance of external suppliers (e.g. FSE scorecards and manpower provider scorecards). On time delivery of parts and materials is important for Alpha, as is identifying the root causes in the instance that on-time delivery (OTD) is not 100%.	●●●●●	●●●●●
Supplier relations	Alpha has a number of relationship types with its suppliers. These include Turnkey contracts, Global contracts, Time & material push type contracts and blanket orders with a lump sum approach.	●●○○○	●●○○○
Customer relations	Alpha has a constant focus on customer satisfaction, as demonstrated by its maintenance-driven outage planning strategy. Planning for an outage begins 24 months prior to execution, and on-time start is critical as one day of lost production costs the customer a lot of money. As such, customer meetings begin in the planning phased 18 months prior to planned start date, and both the capital and service parts are ordered 12 months before start. The FSE is confirmed 6 months before the scheduled start date, and throughout the execution phase, a dedicated tool is used to evaluate real-time performance.	●●●●○	●●●○○

Figure 1 – Alpha



Alpha's strong focus on Six Sigma is apparent with such high scores in both Performance measurement and Quality control. There is also a very strong focus on Planning and control in Alpha's service operations.

4.2. Toyota Motor Italia (TMI), Rome, Italy

Toyota Motor Italia (TMI) in Rome, Italy, is the headquarters of Toyota in Italy and serves as a hub for Toyota's Italian operations. The organization is structured such that TMI operates as a division of Toyota Motor Europe (TME), itself under Toyota Motor Corporation (TMC) in Japan.

As a company, Toyota is widely regarded as the best-in-class lean producer, with the development of the Toyota Production System (TPS) itself attributed to the conception of the lean production paradigm.

TMI in Rome is responsible for new vehicles and spare parts sales and distribution. The spare parts warehouse serves approx. 100 dealers in Italy with spare parts on a daily basis. TMI is also responsible for diffusing Kaizen (continuous improvement) initiatives throughout all Italian dealerships. As such, there is a great focus on avoiding and eliminating muda (waste) within the supply network, and TMI are responsible for teaching dealers how to order parts on a just-in-time (JIT) basis (i.e. "the right part in the right quantity at the right moment"). Through its 100 dealers, TMI offers to its customers a wide range of product-oriented services, from repair activities and maintenance contracts, to extended warranties, through to genuine parts supply.

TPS is the framework that guides the parts logistics operations at TMI, and as such, TMI is recognized as being one of the best service supply networks within TMC. By fully implementing TPS and the JIT concept in the dealer network, TMI has been able to increase stock turns from 24 to 48 per year, with a resultant saving of €32k in stock value per dealer.

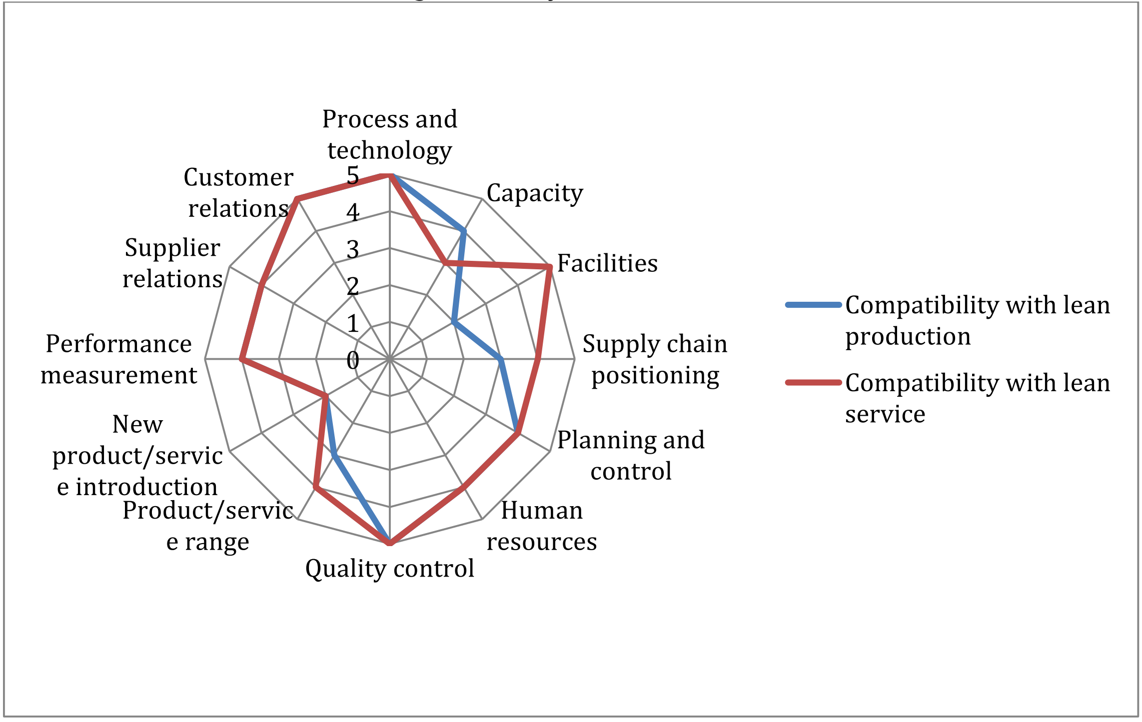
The interviews at TMI were carried out on March 14th 2014, with two interviewers and a total of 3 interviewees. The results are shown in Table 3:

Table 3 – Case description in the perspective of lean PSS operations – Toyota Motor Italia

Characteristic	TMI's PSS lean operations	Compatibility with lean production	Compatibility with lean service
Process and technology	TMI uses standardized processes and simple, proven technologies in line with the TPS philosophy. Lean tools and techniques are applied in the warehouse just as they are in the factory, e.g. Andon is used for visual management, Kanban is used to re-order parts and components, and Heijunka is used to level the daily activities.	●●●●●	●●●●●
Capacity	Capacity in the warehouse is levelled based on the number of trucks arriving and through the use of standard work and cycle times / pitch times (e.g 15 mins). This information is shown visually on the workforce schedule.	●●●●○	●●●○○
Facilities	TMI's spare parts network is managed centrally from the warehouse in Rome. The layout of the dealers' parts depots are a reflection of the layout at the central warehouse. Because parts are ordered and replenished individually and on a daily basis, TMI's dealer parts depots occupy approx. 25% of the space required by its competitors (e.g. $100m^2$ compared to $400m^2$). Layout is designed based on the "Seven storage techniques" of TPS.	●●○○○	●●●●●
Supply chain positioning	TMI operates a very vertically integrated supply network, and "Italian dealers that order today by noon will receive tomorrow by 7am". Also, 99.8% of parts that need to be replenished in the central spare parts warehouse from TMC Japan or TME Europe will be achieved within 5 days.	●●●○○	●●●●○
Planning and control	The main target at the dealership is to avoid fluctuations – Heijunka is the goal. If the dealer can order every day, the central warehouse can follow demand without problem. An appointment booking system is used at the dealerships, which acts as a workshop visual management system. As such, it is very important to pre-book the parts for all the scheduled job, in order to achieve the target service level.	●●●●○	●●●●○
Human resources	Technicians in the service network are multi-skilled. A technician achieves master-technician status depending on the quality of his diagnostic ability. As such, a master-technician will never be used for basic maintenance tasks. Dealers adjust to their own requirements for multi-skilled manpower. In order to avoid repetitive, dispiriting work, job rotation is used, and jobs are shifted on a weekly basis. This helps to ensure "fresh eyes" on a job to identify problems.	●●●●○	●●●●○
Quality control	Standard operating procedures (SOPs) are used to ensure the desired quality standard is achieved in the various processes. There is a checklist of parts for each job, as well as a quality checklist that is used to evaluate the job against the action plan. On specific key processes (e.g. active reception of the customer), field people monitor and evaluate the service quality on a weekly basis, and produce a specific action plan based on the findings.	●●●●●	●●●●●
Product/service range	In terms of the service range, the workshops and dealerships aim to be a "one stop shop", providing everything form tyres and body shop to financial services – "the dealer should leave no space for competitors".	●●●○○	●●●●○

New product/service introduction	Product design is carried out at a higher level (e.g. TME/TMC), but new services can be developed based on local needs (e.g. tyre services).	●●○○○	●●○○○
Performance measurement	TMI use seven core KPIs to manage its operations (at dealer level): technical efficiency, turnover, number of Duotec (fast maintenance) operations, inventory turnover, service absorption (overhead costs covered by after sales profits), customer retention, and customer satisfaction.	●●●●○	●●●●○
Supplier relations	TMI uses a single key supplier in the packing and shipment process in the central warehouse (SUSA) and also uses 4 or 5 strategic "consultant" suppliers (e.g. JMAC) that are fully involved in strategy deployment.	●●●●○	●●●●○
Customer relations	Customer perception is an important assessment metric for TMI. Before the Kaizen activity with the dealer network, a pre-Kaizen survey was distributed amongst its customers in order to achieve the best result in terms of the customer. TMI standards are established in line with customer perception.	●●●●●	●●●●●

Figure 2 – Toyota Motor Italia

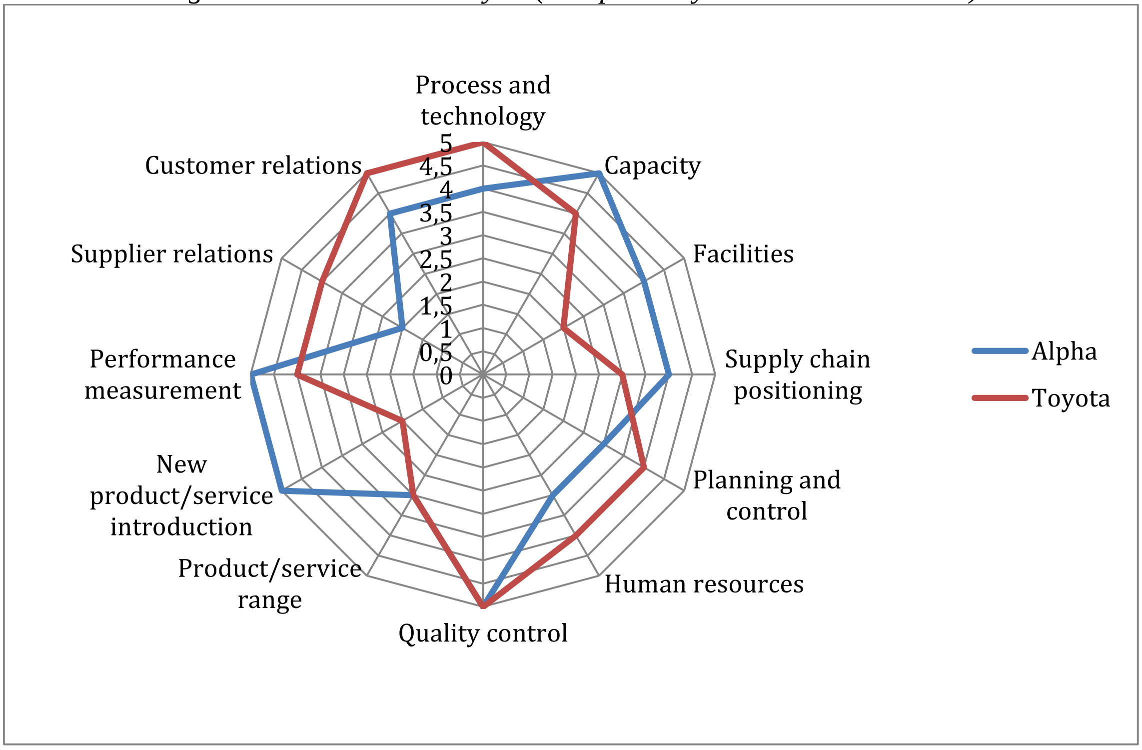


As the best-in-class lean producer, it was clear that the high level of expertise had been translated into Toyota's service offerings. As such, TMI rated maximum in the dimensions Customer relations, Process and technology, and Quality control, in both the production and service context. Supplier relations, Performance measurement, and planning and control were also equally highly rated between production and service contexts. Major differences were in the facilities dimension, though this is somewhat logical due to the centralised nature of the spare parts warehouse in respect of the service workshops that are geographically dispersed at the TMI dealerships.

5. The theoretical framework

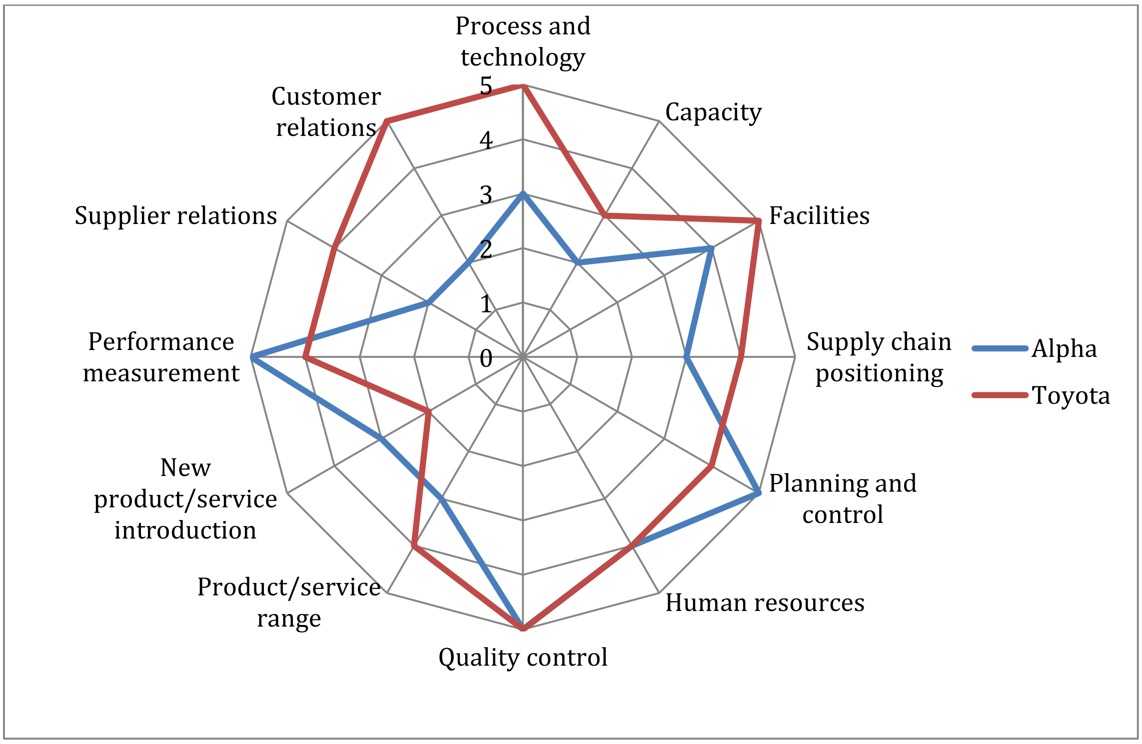
Cross-case analysis was carried out in order to improve understanding and explanation, and to increase the generalizability of the findings (see Figures 3 & 4). In terms of the compatibility with lean production operations, the two best-in-class lean companies scored well in Customer relations, Process and technology, Performance measurement, and quality control. The major differences between the two cases were evident in the dimensions New product / service introduction and Facilities.

Figure 3 – Cross-case analysis (Compatibility with Lean Production)



In terms of compatibility with lean service operations, this is where we suggest that the two companies diversify themselves to the greatest extent. For example, where Alpha adopt a strong focus on Quality control, Performance measurement and Planning and control; TMI maintain a strong emphasis on Customer relations and Process and technology.

Figure 4 – Cross-case analysis (Compatibility with Lean Service)



Combined with our findings from the literature review, the comparison and analysis of the two case studies was subsequently used to construct the theoretical framework, as shown in Table 4:

Table 4 – Theoretical Framework: Lean Operations in Product-oriented PSSs

Characteristic	**Lean *Product-centric* PSS operations**
Process and technology	Tend to utilize standardized processes and simple, proven technologies (advanced technologies are avoided due to possible negative effects of the use of "black-box" solutions, and should only be applied once they have been sufficiently proven in practice). Tend also to focus on continuous improvement of process quality and use thoroughly tested technology to reduce necessary, non-value adding activities (Type 1 muda).
Capacity	Tend to aim for spare capacity for flexibility to avoid delays, which result from overutilization of resources. Tend also to create a level schedule to support continuous material flow. Extra workers are added to the system to reduce takt-time only if full capacity is reached.
Facilities	Service facilities tend to be distributed and located optimally with the needs of the customer in mind, whilst inventories and warehouses tend to remain more centralised with effective and regular distribution in mind.
Supply chain positioning	Tend to maintain both vertical and horizontal integration. Internal "lean production" structure tends to be replicated outside of the manufacturing process in terms of lean procurement, distribution and partnership. Long term relationships with suppliers & supplier development are also fundamental.
Planning and control	Tend to aim for product availability, firstly by reducing lead times, and then by increasing reliability of the product through high service levels (high customer orientation).
Human resources	Tend to consist of a core team of multi-skilled and multi-tasked operatives, both in-house and in-field. These have good product knowledge and understanding of customer value creation.
Quality control	Tend to maintain a system of quality control whereby measures are taken to guarantee product quality in production, as well as to maintain product

	quality during operation in the hands of the customer.
Product/service range	Tend to offer standardized yet customizable products (mass-customization) with a variety of choices of supporting services, where efforts are made to reduce variation.
New product/service introduction	Tend to have a core cross-functional team that is responsible for the development of new products and supporting services, with input from the customer and key suppliers.
Performance measurement	Tend to use a core set of balanced measures (e.g. a Lean PSS Balanced scorecard approach) that emphasizes system effectiveness and that is aligned with the strategy of the business. Activities are coordinated and evaluated by the flow through the team or plant, not by individual departmental targets.
Supplier relations	Tend to work closely with suppliers in order to reduce supplier lead-times and increase supplier quality, e.g. supplier development. Long-term supplier relationships are deployed. As such, suppliers are an integral part of the Lean PSS operations.
Customer relations	Tend to focus on customer value which requires close contact with customers. Wasteful (non-value adding) activities are systematically identified and eliminated. Customer-focussed value creation is the main criteria for Lean PSS, and customers are an integral part of Lean PSS operations.

6. Conclusion, limitations and further research

Through the investigation of various product-service offerings at the Italian headquarters of both an automotive supplier and a turbine producer, this work is a first step toward the construction of a theoretical framework for the planning and management of lean PSS operations. In particular, we make a contribution by expanding Baines et al.'s (2009) framework for product-centric servitization to consider the systematic application of lean thinking in managing PSS operations. The framework can be used to help researchers understand the challenges in delivering value through a PSS solution and provides future research directions and questions, moving beyond reasoning about general features of PSSs and addressing the evolution of PSS providers' organisation and operations, both internally and externally of the focal organisation.

We believe that this model may serve different needs: i) describing the existing PSS operations strategy, ii) identifying its strengths and weaknesses, and iii) supporting the application of lean approaches and methods to improve PSS operations. Moreover, the framework, which has been developed through analysing two companies that are themselves recognized as best-in-class in the adoption and application of lean approaches, shows the ability to act as a descriptive mapping tool for analysing a firm's capabilities, competences and organisation required to match the offers provided. Indeed, it will help managers to support service activities, simplifying the analysis and re-engineering (if necessary) of the structure of a PSS business model in order to develop Lean PSSs.

However, the model cannot be considered exhaustive and presents some limitations that can be overcome by further research:

- We developed our research considering the impact of a lean approach on PSS at an operational point of view only. On the contrary, as widely demonstrated in literature, the success of any PSS initiatives does not depend solely on applied tools and techniques, but is strictly related to the way in which companies operate. This affects organisational structures and processes and requires a shift of the mindset that pervades the overall organization and the value network in which a company operates. In such a sense, a lean initiative could be very helpful for companies embarking on a servitization journey. As already demonstrated and discussed in literature, the success of lean is achieved not just through applying good operational methods and approaches, but also through establishing a clear vision and strategy. The top level management must also be highly committed and adopt adequate methods to communicate the company strategy, in order to support the competence development and the diffusion of lean culture and mind set across the overall organisation. In such a sense we believe that future research is required to advance the comprehensive perspective of our proposed framework, including strategic, managerial, structural, and organisational angles.

- We developed our framework taking into account a Japanese company and an US company, both operating in Italy. An enlargement of the sample including other cases, countries and sectors could allow an evaluation of the applicability of the framework in different types of business and cultures. This should include an investigation of how to use the framework to manage the whole Product-Service network including all stakeholders (product and service providers) that are involved in development, management and control of new PS solutions.
- Finally, the adopted framework includes only a product-oriented PSS point of view. We suggest enlarging the perspective to both use- and result-oriented PSSs, in order to analyse how these PSS types differ from product-oriented solutions with regard to lean PSS operations.

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