Product-Service Systems across Life Cycle

Lean and Green Supply Chain for the Product-Services System (PSS): The Literature Review and A Conceptual Framework

Ai Qiang Li,a,* Pauline Founda

*Corresponding author. Tel.: +44 7519 490036; E-mail address: 1500508@buckingham.ac.uk

Abstract

In recent years, the distinction between manufacturing and services has been blurring. They are often combined together to provide customers a total offering for better economic performance. At same time, manufacturers are facing rising pressures from government, society and end users to reduce the impacts of their products and services on environmental sustainability throughout the supply chain. As a result, Product-Service System (PSS) was developed to drive for both business excellence and environmental sustainability. The application of Lean and Green thinking in supply chain management has also shown the advantage of addressing the two issues. However, there is a lack of systematic research on how Lean and Green thinking could support the development of PSS supply chain, esp. in the fields of supplier collaboration and relationship development across the product life cycle. For instance, how can Lean and Green help reshaping the supplier structure and network? Which Lean and Green tools can promote the supplier relationship? From literature review, this paper summarizes the state-of-art researches on PSS, Lean/ Green supply chain management and the connections between them. Then a conceptual framework of Lean and Green supply chain for PSS is constructed to guide the case studies in next steps.

Keywords: Lean and Green Supply Chain; Product-Services System (PSS); Conceptual Framework; Supplier Relationship.

1. Introduction of manufacturing industry – a UK Case

In UK, although the manufacturing share of its GDP has dropped from about 18% in 1990 to around 10% in 2010, it is still a critical contributor to other significant indicators such as exports, innovation, inter-industry linkages, etc. [1]. For example, manufacturers play a leading role in innovation. In 2010, 26% of UK manufacturing businesses engaged in process innovation and 44% in product innovation. The data for non-manufacturers was less than 14% and 26% respectively. Manufacturing industry also connects other industries through its wide range of forward-backward. The calculation from U.S. Bureau of Economic Analysis shows that every dollar sold from manufactured goods will create another 1.33 dollars of contribution towards other industry sectors, which is the largest multiplier and almost doubles the effect of financial services [2]. In UK, the linkage of manufacturing with the forward and backward sectors are 1.6 and 1.0 respectively, which ranks top of all other industries [1].

Kitson and Michie [3] argued that the relatively decline of GDP share of UK manufacturing since 1960s indeed reflected deep-rooted structural problems: the UK economy was too heavily dependent on financial services. There are increasing debates that UK economy should shift to manufacturing to retain a sustainable economic future, because a stronger manufacturing sector would help to rebalance the UK economy. In order to recall its global leading position and competitive advantage in manufacturing, the UK government published a report of Manufacturing the Future in 2013, which predicts that the manufacturing industry in future will change considerably by becoming more sustainable in manufacturing and its supply chain and more than just offering a product - towards ‘physical products plus services’ [1].
2. PSS, Lean, Green and the Supply Chain

2.1 Introduction of PSS

Brown [4] pointed out that the distinction between manufacturing and services has blurred. There are lots of interlinking activities between manufacturing and service operations and they are often combined together to provide a total customer offering within the supply chain. Further, product and process based manufacturing is relatively easy to imitate by competitors, but a total solution of products and related services is less easy to replicate [5]. Therefore, many governments and manufacturers have been engaging in the evolution from pure product-focus to a combination of physical products and related services - the Product-Services System - to gain industrial sustainability and competitive edge [1,6-8].

The term Product-Services System (PSS) was first introduced during the late 1980s and mid-1990s by some authors of the environmentalists [6,9]. Believing that the material and energy efficiency of industrial economy is low, they proposed to substitute products with services to reduce the environmental burden [9,10], because they thought the shift of focus from products to customer final need (such as products plus services) could greatly improve sustainability [6]. This is supported by the idea that manufacturers only sell the product function to customers instead of the product itself [10]. In this case, manufacturers hold the product ownership and are responsible for its update, maintenance and recycle across the product lifecycle, therefore, they are more motivated to design and produce best possible products to reduce their own maintenance costs and to reuse or recycle as many parts as possible [7].

From the late 1990s, a number of authors started to work on the definition, concept and methodology development of PSS [9,10]. There are different definitions of PSS [6,11,12]. For example, Mont [13] defined PSS as “a system of products, services, supporting networks and infrastructure that is designed to: competitive, satisfy customer needs and have a lower environmental impact than traditional business models”. Tukker [11] claimed PSS “consists of tangible products and intangible services which are designed to jointly fulfill the final customer needs”. However, the definitions of PSS are too general and vague [9], particularly on the meaning and scope of services. The word ‘product’ is generally well understood while the term ‘services’ is often used loosely [8]. We argue that for a PSS, firstly it should be based on a physical product, which is tangible and manufacturable within a manufacturing context. This means other kinds of ‘product’ such as financial products do not constitute a ‘product’ of PSS. Secondly, the meaning and scope of services needs a clear interpretation. Baines et al. [8] regarded services as an offering of “economic activity that does not result in ownership of a tangible asset”. Thus, we suggest that an explanation of ‘services’ follows the definition of PSS: “A Product-Service System is a business shift from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands [14]. Here, services mean an economic activity that does not result in ownership of a tangible asset.”

Tukker [11] summarized three main types of PSS: the product-oriented PSS, which includes product repair, refurbishment, recycle, spare parts and consuming material management, training, consulting, etc.; the use-oriented PSS, which includes product renting, leasing and pooling; the result-oriented PSS, which includes activity management or outsourcing, pay per service unit, etc. With companies moving into PSS, there is a change of customer interactions from the transaction-based to relationship-based [15]. Baines et al. argued that customer centrivity will be the key features of servitization [8]. Kano’s theory of attractive quality indicates that the attributes of product and service are dynamic with the change of customers value and perception, for example, from being indifferent, to attractive, and to must-be [16]. Thus, there should be a fourth type of services, i.e. the market (attractiveness)-oriented services for ‘delighter’: unlike the three ‘must-be’ services, this kind of services look at the future of market (customer) needs.

Regarding sustainability, many authors agreed that PSS could produce positive environmental effects [1,6-9,11], although some argued that PSS does not necessarily bring environmental benefits [11,14,17,18]. For example, Tukker [11] claimed that most PSSs could probably bring environmental improvements. However, the assumption that PSS will intrinsically lead to an environmental-economic dual-win seems to be a myth [11]. Sakao et al. [18] found companies which shift to services with business motivations do not realize the environmental potential. This is also supported by Sundin et al., who argued that although PSS could bring companies environmental sustainability, sustainability is not always the main reason of moving into PSS [19].

Since 2010, there has been more business case studies which show that the move to PSS helps enterprises to achieve environmental sustainability. For instance, Kurde studied the Fluid Management Services (FMS) in Volvo and found that the adoption of PSS (together with lean program) bring many environmental gains [20]. The Nordic countries published a report on Green Business Model Innovation [21] in 2012, in which case studies show that 11 case companies out of the 29 samples choose Functional Sales (PSS) as the major green business models. Companies which adopted PSS for their Chemical Management Systems reported profound environmental gains. For example, Nortel reported 8% less hazardous waste emission, Raytheon Systems reported 71% reduction in paint waste, and Navister engine plant gained a 90% reduction of coolant waste [21].

Literature also revealed the drivers and challenges for organizations’ moving to PSS. For instance, Mont [9] identified external drivers such as environmental legislation and market demands and internal drivers such as resource recycle and environmental performance improvements. Mont and Lindhqvist [10] argued that environmental regulations are the main external drivers for the advancement of PSS. Baines et al. [8] summarized three drivers:

- Financial drivers for higher profit and income stability;
- Strategic drivers for gaining competitive edge, with services to differentiate the manufacturing offerings;
• Marketing drivers for customer loyalty by reinforcing contact opportunities with customers, which enables companies to catch customers’ needs timely to develop more tailored offerings.

Uлага and Reimartz [22] investigated that manufacturers are facing challenges of balancing the resources of salespeople to sell products, services, and the combinations. Oliva and Kallenberg [15] thought there are two major challenges during this transition: the cultural change from a product-focused organization to a service-oriented one and the necessity of establishing a global service network capable of responding promptly to local customers. Baines et al. [8] summarized three challenges of product-service design, organizational strategy and organizational transformation.

Particularly, there are increasing findings on challenges of supplier network and relationship. For example, Martinez et al. [5] considered external supplier relationships as one of the five challenges because the product related services are normally provided by other partners in a broader supply network. The complex integrated PSS requires a sound alignment of mindset and understanding between PSS provider and suppliers. The service component in a PSS is more easily managed by relation than by transactional exchange because services is normally regarded as ‘ tacit know-how assets’ [5]. Nudurupati et al. [23] claimed supply network as one of the eight challenges and asked if it is needed to vertically integrate them. Lockett et al. [24] conducted an exploratory case study on PSS and supply network relationships. They found that the adoption of a PSS may work negatively on companies’ supply chain if the suppliers are not well integrated and aligned. Effective information sharing throughout the PSS supply network is essential.

2.2 Lean Supply Chain Management (LSCM)

Supply chain management (SCM) first came as a term in 1982. According to the definition from Institute of Logistics and Transport, “the supply chain is a sequence of events intended to satisfy a customer. It can include procurement, manufacture, distribution and waste disposal, together with associated transport, storage and information technology” [25]. Lean is a management philosophy which originated from Toyota. Since the publication of The Machine That Changed the World, it has become widespread in manufacturing and services [26–30]. Lean supply chain management applies lean thinking to eliminate non-value added activities across the supply chain [31,32].

Ugochukwu et al. [33] conducted a comprehensive literature review on Lean supply chain. The findings indicate that almost every article focuses on supply and manufacture and half of the articles talked about distribution and end customers. The majority of the articles look at the manufacturing with only two on services. In terms of research methods, case study was widely used, followed by the conceptual and survey approaches. The research limit on supply and manufacture and neglect of others such as product design, transportation and distribution may also restrict the exploration of the boundaries.

In particular, a number of the researches worked on analysing the vital factors which significantly influence the Lean supply chain. For instance, Nightingale [34] argued that supplier partnerships and strategic alliances are the two key features of LSCM which differs remarkably from the conventional supply chain practices. Found [35] discussed the behavioral perspective of Lean supply chains and concluded that a contingency approach considering all the variables such as mutual trust and equity is necessary to design an effective and sustainable Lean supply chain. Mollenkopf et al. [31] summarized that Lean supply chain requires high levels of information sharing, fast improvements with suppliers and minimal transaction costs. Simpson and Power [36] argued that the lean supply relationship is a key to the success of lean production and open communication is important to develop and maintain the relationship.

2.3 Green Supply Chain Management (GrSCM)

In recent years, companies are facing increasing pressures from the government, society and end users for their environment performance. They are expected to reduce the impacts of their products and services on environmental sustainability throughout the supply chain [37,38]. As a result, Green Supply Chain Management (GrSCM) has been evolving with interests from both academia and businesses [39].

However, the terminology of GrSCM concepts varies over the years and there is a lack of shared definition [39–42]. For example, Sarkis and Zhu [39] defined GrSCM as “integrating environmental concerns into the inter-organizational practices of SCM including reverse logistics”. Hsu [43] argued that a GrSCM aids at minimizing environmental impacts of a product throughout its entire lifecycle, which includes green design, product recycle, etc. Yu [44] defined GrSCM as “the intra and inter-firm management of the upstream and downstream supply chain, which has the capability to minimise the overall environmental impact of both the forward and reverse flows”. Srivastava [45] defined GrSCM as “integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life”. As Lo [46] summarized, all the definitions of GrSCM contains two crucial factors: environmental impact and supply chain management. He described GrSCM as “including all environment-relevant practices, relationships among chain partners, and the minimization of the impact of firm practices on the natural environment through the use of recycled products/services”.

There are also many authors using the term sustainability or environmental sustainability for supply chain management, which brings confusion between sustainable supply chain management and green supply chain management [40]. Sustainability incorporates the concept of sustainable development including the three dimensions of ‘triple bottom line’ (3BL)’ [40,47], rather than only focusing on ‘green’ or ‘social’ [47]. To avoid the confusion, we use the term sustainable supply chain in a default perspective to describe environmental sustainability [40], which is an exchange of green supply chain.
Many authors found that GrSCM could positively affect companies’ environmental and economic performances [44,46,48]. The success of addressing environmental issues can bring organizations new opportunities of creating an additional source of income, for example by taking back and reselling the refurbished products [43]. Interestingly, Dam and Petkova [38] investigated the relationship between shareholder value and firms’ announcement of participating in environmental supply chain sustainability programs (ESCSs). The result showed firms announcing participation in ESCPs brings a negative stock price reaction. If firms have faced higher pressures from consumers in the past, they are less likely to announce the participation. They also pointed that consumer perceptions about organizations’ environmental supply chain sustainability do not match the reality, which imposes pressures on them to join additional environmental programs (greenwashing) to show the public their actions.

Researches also summarized that key drivers for the GrSCM include environmental policy [43,49,50], customer requirements [43,50], green associations [51], competitor pressures [43], green collaboration with supplier [52–55], green supplier assessment [49,52,54], green human resource management [49], green/eco-design [49,51], etc. Barriers include resistance to adapt technology advancement [50,56], costs of implementation [31,50], uncertainty [55], short of knowledge and expertise [56], lack of government support systems [56,57], absence of management commitment [56,57], and accounting methods targeting on short term measures [56].

Noteworthy, many authors regarded ‘green collaboration with supplier’ as one important driver [52–55]. Thus, we assert that supplier relationship (of green collaboration) is a key element for companies to improve the environmental sustainability of their products and services [36]. For example, Taizhizawa et al. [53] found that supplier (green) assessment and monitoring alone doesn’t affect organizations’ environmental performance directly but joint collaboration with suppliers have significant impact on the performance. Lo [46] found the uncertainties a company faces during green practices connect with its position in the supply chain. Companies at the downstream of a supply chain are more likely to practice green design, purchase, and internal environmental management. Companies at midstream of a supply chain tend to focus on green manufacturing and logistics. The findings could support companies in deciding the ways of collaboration.

2.4 Lean and Green Supply Chain Management (LGrSCM)

In order to achieve both economic performance and environmental benefits, a few organizations and researchers have been exploring the integration of Lean and Green thinking. For instance, Florida [58] argued that the application of lean production system provides another opportunity of applying green design and manufacturing because they share the underlying principles. The United States Environmental Protection Agency (EPA) published The Lean and Environmental Toolkit in 2006 to provide practical guidance for integrating environmental considerations into Lean initiatives to eliminate environmental wastes [59]. According to EPA, “Environmental waste is an unnecessary or excess use of resources or a substance released to the air, water, or land that could harm human health or the environment. It can occur when companies use resources to provide products or services to customers, and/or when customers use and dispose of products”. Identifying and eliminating wastes is the cornerstone of Lean initiatives. However, the environmental waste is often unaddressed (or under addressed) by Lean initiatives [59]. Including environmental considerations or green elements into Lean efforts could catalyze Lean implementation and deliver better results [60–62]. Pamparrelli and Found [63] developed a Lean and Green Model which integrates Lean philosophy and Green thinking by merging the fundamental principles of Lean and Green. The model was verified in production cells of a global manufacturing and engineering company. The environmentally sustainable practices can be treated as an extension of Lean philosophy.

There are not many researches exploring the Lean and Green supply chain. For example, Dues [60] argued that Lean and Green supply chain practices are not well connected yet. Simpson and Power [36] pointed out that the customer-supplier relationship is very important to develop Lean and Green suppliers. Information sharing between customers and suppliers is important for the supply chain development. Florida [58] found that the end-user/supplier relationships foster the diffusion of lean manufacturing with environmental conscious. For example, the collaboration between end users and suppliers in (lean) product development will help to create innovative products and processes to reduce wastes and protect the environment.

2.5 Lean in PSS

Although there are fruitful researches and practices on both Lean manufacturing and Lean services [26,30], there is an apparent lack of knowledge on how to combine the success of Lean thinking with PSS [64]. By searching for Lean PSS (or Lean Product-Service System) in Google Scholar and EBSCO Discovery, only 3-4 papers can be found and all of them are published in 2015. For instance, Azevedo and Shohlib [65] argued that lean costing system is the best choice to support the proposed framework of PSS function-oriented services. Timely and reliable exchanges of information and knowledge between PSS providers and customers is highly required.

Sassanelli et al. [66] summarized the latest research on PSS design by applying Lean Thinking. The authors pointed out that although there are considerable researches on PSS design, there is still little work done on the potential role of Lean Product Development methodologies both from the academia and industrial practices. It is suggested that in order to improve PSS design with Lean thinking, it is necessary to share knowledge and best practices among different partners such as industrial practitioners and experts in Lean, PSS design, and computer aided engineering. The authors also identified a few potential research challenges such as: how to define waste and value in a PSS design process and how IT tools should be reshaped to support the PSS design process in the Lean way? Resta et al. [64] proposed a theoretical framework for lean product-oriented PSSs by adopting a multiple case study approach in Italy. The framework includes 12 characteristics of operations
such as customer relation, supplier relation and supply chain positioning. It can help organizations to interpret the current PSS operations strategy, identify its strengths and weaknesses and to consider the application of lean thinking to improve PSS operations in a systematic way. Elnadi [67] developed an innovative framework to implement Lean principles in PSS context and a Leanness assessment model to measure the Leanness level of a PSS. The author indicated that supplier relationship is one of the enablers and multi-sites of the company is a challenge for Lean application in PSS. Kaizen and 5S are the two most used Lean tools in PSS. However, the author does not explore further on the peculiarities of PSS supply chain and how to manage the PSS supply chain, esp. for those international corporations with multi-site companies by adopting Lean (green) thinking.

3. LGrSCM for PSS: A Conceptual Framework

As shown above, both Lean and Green thinking have been adopted in the supply chain management to drive for business excellence and environmental sustainability. Literature indicates that supplier collaboration and relationship is a key to the success of LSCM or GrSCM [34,36,52–55]. With the evolution to PSS, companies are facing increasing challenges such as the broader supplier networks and more complex relationships between PSS providers and their suppliers [5,23,24]. Combining with other important findings, we tend to conclude there are three key peculiarities of the PSS supply chain: impact of product ownership on organizations’ and stakeholders’ behaviour, timely and reliable information exchange, complex network and relationship between PSS providers, stakeholders and end users. Therefore, there is a great need of a systematic research on those peculiarities and how Lean and Green thinking can support the PSS supply chain development. For instance, how can Lean and Green thinking help reshaping the supplier structure and network? Which Lean and Green tools can promote supplier collaboration?

To make this process visual and clear, a conceptual framework of Lean and Green Supply Chain of PSS is constructed, as shown in Fig.1. The outer big circle of the framework includes the stakeholders during different stages of the PSS supply chain. Their relationship network and ways of collaboration will be one of the research aims. The inner small circles represent different steps starting from resources available to product design, manufacturing, distribution, use, services and back to resources through material recycle. The material flow goes in the same sequence, but there are two-way movements between steps of manufacturing, distribution, use and services, e.g. the components recycle process.

Between the outer cycle and these small inner cycles is the information flow. As explained earlier, information (and knowledge) sharing between all players and stakeholders is regarded as essential for PSS [24,65,66] and Lean, Green supply chain [31,36]. Information sharing could be supported by the recent fast growth of digital industry, which fosters the new trend of Digital PSS [68] and may provide product manufacturers and logistics partners new opportunities of collaboration in simplifying the supply chain, e.g. by producing the parts closer to points of maintenance [69].

In the middle of this framework stands Lean and Green thinking, the core part facilitating to connect the individual process and stakeholder through the whole PSS supply chain.

Fig. 1 The Framework of Lean and Green Supply Chain in PSS

4. Summary and Next Steps

This paper summarizes the state-of-art research on PSS and Lean/Green supply chain management through literature review. A conceptual framework is constructed as a guide to explore how Lean and Green thinking enable PSS supply chain development. As a next step, case study is proposed with a focus on the product-oriented PSS. Case study will be conducted in UK and China. This is because firstly China is among the top countries in terms of manufacturing competitiveness and volumes and there is an increasingly huge PSS market for global players [1]. With globalization, PSS design and ‘assembler’ may be in UK and PSS suppliers and end users may be largely in China. Secondly, both UK and China have highlighted the strategy of Green (Sustainable) Manufacturing and PSS in the national level, e.g. by UK Manufacturing the Future (2050) and China Manufacturing 2025. Thus, we believe the collaboration between UK and China will provide valuable inputs for the propose research.

References
