

State-of-the-art in product service-systems

T S Baines*, H Lightfoot, E Steve, A Neely, R Greenough, J Peppard, R Roy, E Shehab, A Braganza, A Tiwari, J Alcock, J Angus, M Bastl, A Cousens, P Irving, M Johnson, J Kingston, H Lockett, V Martinez, P Michele, D Tranfield, I Walton, and H Wilson
Department of Manufacturing, Cranfield University, Cranfield, UK

The manuscript was received on 28 February 2007 and was accepted after revision for publication on 25 June 2007.

DOI: 10.1243/09544054JEM858

Abstract: A Product Service-System (PSS) is an integrated combination of products and services. This western concept embraces a service-led competitive strategy, environmental sustainability, and the basis to differentiate from competitors who simply offer lower priced products. This paper aims to report the state-of-the-art of PSS research by presenting a clinical review of literature currently available on this topic. The literature is classified and the major outcomes of each study are addressed and analysed. On this basis, this paper defines the PSS concept, reports on its origin and features, gives examples of applications along with potential benefits and barriers to adoption, summarises available tools and methodologies, and identifies future research challenges.

Q1

Keywords:

1 INTRODUCTION

The concept of a Product Service-System (PSS) is a special case of servitization. A PSS can be thought of as a market proposition that extends the traditional functionality of a product by incorporating additional services. Here the emphasis is on the 'sale of use' rather than the 'sale of product'. The customer pays for using an asset, rather than its purchase, and so benefits from a restructuring of the risks, responsibilities, and costs traditionally associated with ownership. Similarly, the supplier/manufacturer can improve their competitiveness as these 'solutions' may be clearly differentiated from product-based offerings while simultaneously retaining asset ownership that can enhance utilization, reliability, design, and protection.

For some authors the concept of a PSS also embraces sustainability. The underpinning expectation is that a pure PSS will have a lower environmental impact than, simply, a more traditional transaction where an enterprise manufactures products but then transfers responsibilities of ownership and use to the customer. An illustration of both the business and environmental benefits of a PSS is apparent in the Total-Care Package

offered to airlines by Rolls-Royce plc. Here, rather than transferring ownership of the gas turbine engine to the airline, Rolls-Royce (R-R) lease out 'power-by-the-hour'. The gas turbine technology is world leading and the spares and maintenance service they offer exemplary. Furthermore, as R-R maintains direct access to the asset they can collect data on product performance and use. Such data can then enable the improvement of performance parameters (for example, maintenance schedules, etc.) to improve engine efficiency, improve asset utilization, and so reduce total costs and the environmental impact.

PSS is a potentially valuable concept for manufacturers based in developed economies. Manufacturing industries worldwide continue to undergo colossal change. Many traditional producers are increasingly challenged by countries with a low-cost labour base, with the survival of many European operations continuously in doubt, and the relocation of production facilities prolific. There is, however, still a strong desire that the UK should retain a viable manufacturing capability. Manufacturing directly underpins exports, strengthens the service-based economy, and complements the science and engineering research base. Thus, the popular advice to manufacturers is that, to sustain competitiveness, they should 'move up the value chain' and focus on delivering knowledge intensive products and services [1]. Such actions are

*Corresponding author: Department of Manufacturing, Cranfield University, Building 50, Cranfield, Beds, MK43 0AL, UK. email: t.s.baines@cranfield.ac.uk

entirely consistent with the adoption of a PSS-based competitive strategy that uses deep product, process, and customer knowledge to reduce the total cost of a product.

The concept of PSS has been openly discussed in the literature for over a decade (see, for example, Goedkoop *et al.* [2], Mont [3], Meijkamp [4], Manzini and Vezzoli [5]), yet the uptake of such ideas by industry appears limited. Although many benefits are apparent from the literature and existing cases, some major inhibitors are reported to arise across the design and management of engineering, manufacturing, and supply chain operations. However, a concerted and coordinated research programme could address many of these and provide a platform of knowledge and technologies that enable the wide scale adoption by manufacturers of competitive strategies centred on PSS. Such research itself requires a thorough and precise understanding of existing work and so, the purpose of this paper is to describe the state-of-the art with PSS.

The study described in this paper has taken the form of a rigorous literature review. The methodology consisted of identifying relevant publication databases, searching these using a wide range of key words and phrases associated with PSS, and fully reviewing each article identified. From these reviews it was possible to compile a set of key findings. These findings and their implications for research are all described in the paper. Hence, this paper is structured as follows. Firstly, the research methods are described and the initial results of the search for relevant literature are summarized. Key findings are then presented through analysis of the literature. Finally, the results of this analysis are summarized and discussed, and conclusions are drawn.

2 RESEARCH PROGRAMME

2.1 Aim, scope, and research questions

The aim of the research presented in this paper has been to identify, interpret, and summarize the literature currently available on PSS. In determining the scope of this study, the focus has been on articles that are central and relevant to PSS within a wider manufacturing context. An example of a publication that is clearly within the scope of this review is that of Mont [6] in which the author clarifies the concept of PSSs. Similarly, articles that deal with services associated with engineering, supply, production, and after-sales support have all been considered relevant. This strict distinction has been necessary to deal precisely with the concept of PSS. The authors are, however, mindful of the many articles more widely associated with service provision that, although they

fall outside the focus of this initial review, may be translated into a useful contribution to the PSS research activity. These will subsequently receive the authors' attention in a future paper.

In terms of research questions, this study was approached by posing the following questions:

1. What is a PSS and how is it commonly defined?
2. How does an enterprise that deliberately configures itself around PSS differ from a conventional design and make enterprise, and what are the consequences?
3. Where are the leading examples of PSS practice?
4. Where are the strengths and weaknesses in the existing literature?

The purpose of these questions was to guide the search, with the authors being mindful that the existing literature may be insufficient to allow these to lead directly to key findings.

2.2 Search strategy

The search strategy was developed by first identifying the relevant data sources, time frame, and key words. Initially a very broad selection of databases were identified, to cover a diverse range of publication formats including journal articles, conference proceedings, theses, books, and articles from trade journals. These databases included Compendex, Inspec, and Emerald, along with the more traditional library cataloguing systems providing access to a variety of publications from the *Harvard Business Review* through to the *Journal of Cleaner Production*, *Journal of Design Research*, and *Proceedings of Eco-design*. In addition, they provide access to international reports, such as those by the United Nations Environmental Programme and the Dutch and Swedish government departments.

The search strategy initially identified keywords that could be associated with PSS. Examples of these include: servitization, sustainability, service economy, remanufacturing, service design, productization, product substituting service, dematerialization, system solution, and functional economy. Initially, this study focused on literature published between 1995 and 2006, with their citations being cross-checked to ensure that any earlier publications were also captured. The principal research databases were then searched using a range of combinations of these keywords. The lists of hits for each search string were first edited to remove any duplicate records that appeared, the titles were checked to ensure relevance to the review, and then the abstracts of all other articles and papers were reviewed before selecting publications for a full review.

For completeness an Internet search was also conducted using a similar process to that used with the

library databases. The results of these searches combined to provide the following results.

2.3 Results and analysis

Initially, the search terms identified some 80 articles, reports, and theses. These were then carefully filtered to establish 33 documents that were directly relevant to our research enquiry. Subsequent cross-checking of references increased the list to 40, and it is the analysis of these articles ([1–29] and Bibliography 1–11) that forms the basis of the findings in this paper.

The analysis itself was aided by applying mind-mapping techniques to capture and cluster the main themes and contributions. These were then presented at an industrial seminar which helped the researchers to test the clarity and completeness of their findings. These are now discussed in detail.

3 GENERATION OF KEY FINDINGS

The literature review process generated the following nine key findings.

3.1 Definition of a PSS

Clear definitions are an essential starting point for all research and this has been the case with this literature review. The first formal definition of a PSS was given in [2]. Since then, most contributors have broadly adopted this definition (see Table 1), and generally interpret a PSS as a ‘product(s) and service(s) combined in a system to deliver required user functionality in a way that reduces the impact on the environment’. Goedkoop *et al.* [2] add further clarity by also defining the key elements of a PSS; namely:

1. Product: a tangible commodity manufactured to be sold. It is capable of ‘falling on your toes’ and of fulfilling a user’s needs.
2. Service: an activity (work) done for others with an economic value and often done on a commercial basis.
3. System: a collection of elements including their relations.

Most authors see the purpose of a PSS as a competitive proposition, and so directly refer to the need for customer satisfaction and economic viability. In addition, many link PSS with achieving sustainability, but only Manzini *et al.* [7] see this as the ultimate goal. Intriguingly, the concept of dematerialization is frequently discussed in the literature by authors (e.g. Mont [8], Ehrenfeld [9], Manzini and Vezzoli [5], Wong [10], Tomiyama [11]), when describing the concept of PSS. Dematerialization refers to the opportunity that a PSS offers to break the link between value

Table 1 Popular definitions of a Product Service-System

Author (date)	Definition of product service-system
Goedkoop <i>et al.</i> (1999)	‘A product service-system is a system of products, services, networks of “players” and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models’.
Centre for Sustainable Design (2001)	‘A pre-designed system of products, supporting infrastructure and necessary networks that fulfil a users needs on the market, have a smaller environmental impact than separate product and services with the same function fulfilment and are self learning’.
Mont (2001)	‘A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models’.
Manzini (2003)	‘An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands’.
Brandsotter (2003)	‘A PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally PSS tries to reach the goals of sustainable development’.
Wong (2004)	‘Product Service-Systems (PSS) may be defined as a solution offered for sale that involves both a product <i>and</i> a service element, to deliver the required functionality’.
ELIMA (2005)	‘A product service-system is defined as a system of products, services, supporting networks and infrastructure that is designed to [be]: Competitive, Satisfy customer needs, & Have a lower environmental impact than traditional business models’.

delivered to the customer/user and the amount of physical material needed to create that value. While this is often stated as an important aim for many PSS practitioners and researchers, the term does not appear in any of the definitions. This exploration of a definition of a PSS leads the authors to summarize:

3.1.1 Finding 1

A PSS is an integrated product and service offering that delivers value in use. A PSS offers the opportunity to decouple economic success from material consumption and hence reduce the environmental impact of economic activity. The PSS logic is premised on utilizing the knowledge of the designer-manufacturer to both increase value as an output

and decrease material and other costs as an input to a system.

3.2 Evolution of the PSS concept

The first publication on PSS was by Mark Goedkoop *et al.* in 1999 [2]. Titled 'Product Service-Systems – Ecological and Economic Basics', this was commissioned by the Dutch Ministries of Environment and Economic Affairs, and has subsequently been cited by the majority of authors publishing in this field. However, the most prolific author has been Oksana Mont [3, 6, 8, 12], with both Meijkamp [4], Manzini and Vezzoli [5] and Manzini *et al.* [7] also make large contributions. Since the first paper by Goedkoop *et al.* [2] the number of articles on PSS grew steadily, peaking in 2003/4 when 11 papers were published. Since then, there has been a decline in contributions, with the most recent being within a special edition of the *Journal of Cleaner Production* (volume 14) in 2006.

The *Journal of Cleaner Production* has also been the most popular dissemination route for articles on PSS. Here, papers have covered a range of topics associated with the principles, strategies, and developments in PSS. This journal, along with similar technical journals (e.g. the *Journal of Design Research* and the *EcoDesign Journal*) has been the platform for almost 80 per cent of publications. A further 15 per cent of articles have appeared as special reports. Collectively these articles have covered a range of topics, with approximately 20 per cent describing business benefits and drivers (e.g. [2, 6, 7]), 20 per cent reviewing the characteristics of PSS (e.g. [6, 3, 13]), and about 35 per cent focusing on case studies and examples (e.g. [2, 3, 5, 14, 15, 16, 17]). Other topics are related to product life cycle ([18, 19]), service design methods [20], and service engineering [11].

In terms of origin, most authors since 1999 have been Scandinavian (particularly from Sweden), the Netherlands, or Italy. A few articles on PSS have emerged from Asia (e.g. [11, 20]). Surprisingly, there have been no authors from North America directly publishing on the topic of PSS, although several authors do refer to successful applications in this region (e.g. [21, 22]). In recent years more articles have originated in the UK (e.g. [10, 23, 24, 25]). Finally, most authors are from the disciplines of Environment, Sustainability, Economics, and Ecology, with very few contributions from Engineering, Industrial Design, or Manufacturing. This exploration of the origins of PSS leads us to summarize:

3.2.1 Finding 2

PSS originated in Northern Europe (principally The Netherlands and Scandinavia) in the late 1990s and,

to date, most contributors have been academics from environmental and social sciences who typically published in the *Journal of Cleaner Production* between 2000 and 2004.

3.3 Features of a PSS

Traditionally, many people have considered products separately from services. However, recent years have seen the 'servitization' of products and the 'productization' of services. Morelli [14] sees 'servitization' as the evolution of product identity based on material content to a position where the material component is inseparable from the service system. Similarly, 'productization' is the evolution of the services component to include a product or a new service component marketed as a product. The convergence of these trends is the consideration of a product and a service as a single offering – a PSS (Fig. 1). This is consistent with Wong [10] who sees a PSS as fitting into a spectrum where pure products are at one end and pure services at the other.

A PSS features a particular model of business. Here, for example, consider the traditional purchase of a photocopier. As illustrated in Fig. 2(a), the manufacturer provides the technology and, provisionally, the servicing of the technology in the field. In return they are rewarded financially. Although the customer seeks only to use the asset, to do so they have first to purchase the equipment (asset), and then provide the consumables, monitor performance, arrange servicing, and take responsibility for equipment selection and equipment disposal. The responsibilities of ownership lie with the customer.

With a PSS, asset ownership is not transferred to the customer (Fig. 2(b)). In the case of the photocopier, the producer would typically provide 'a document management solution'. Then the producer, rather than the customer, would select and provide

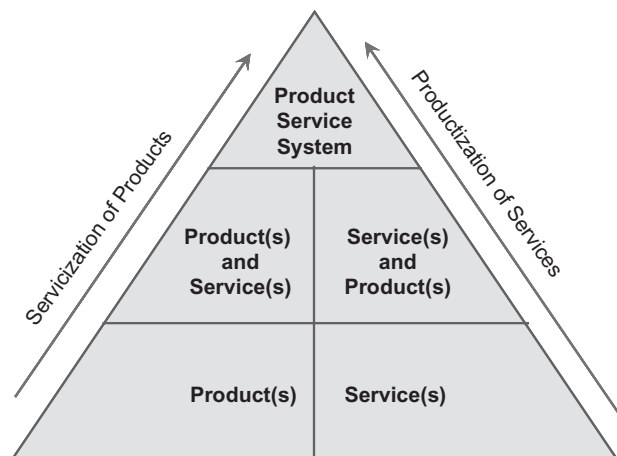


Fig. 1 Evolution of the Product Service-System concept

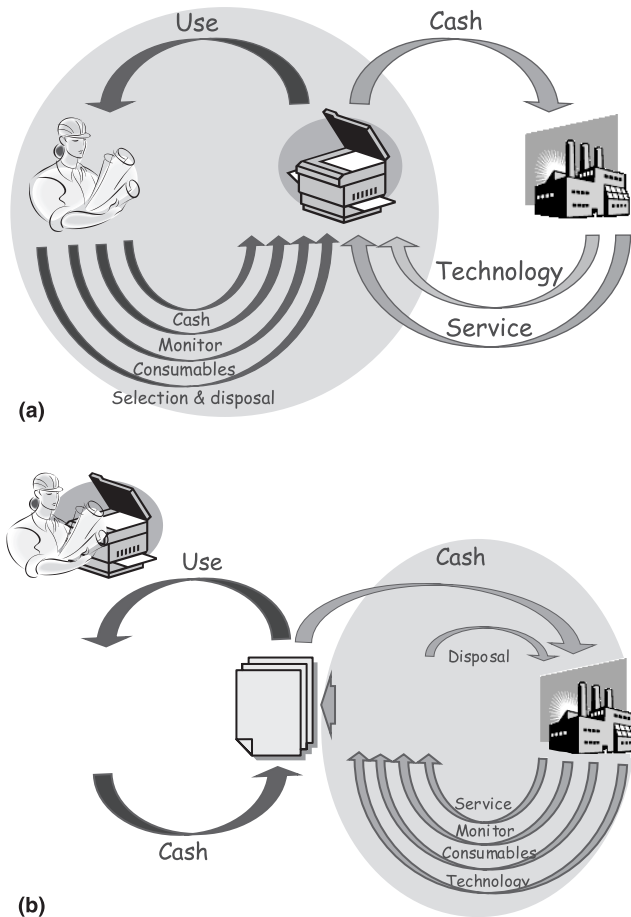


Fig. 2 (a) Traditional purchase of photocopier; (b) Purchase of a document management capability

the equipment and consumables, monitor performance, and carry out servicing and disposal. In return they receive payment as the customer uses the printing capability.

This example illustrates a particular form of PSS that is popular within the literature. Though different authors use different labels and different subdivisions to describe PSS forms, there is some convergence, as highlighted by [5, 7] and [18], on the existence of three different PSS types, namely:

1. **Product-oriented PSS:** promoting/selling the product in a traditional manner, while including in the original act of sale additional services such as after-sales service to guarantee functionality and durability of the product owned by the customer (maintenance, repair, re-use, and recycling, and helping customers optimize the application of a product through training and consulting). The company is motivated to introduce a PSS to minimize costs for a long-lasting, well-functioning product and to design products to take account of product end-of-life (re-usable/easily replaceable/recyclable parts).

2. **Use-oriented PSS:** selling the use or availability of a product that is not owned by the customer (e.g. leasing, sharing). In this case the company is motivated to create a PSS to maximize the use of the product needed to meet demand and to extend the life of the product and materials used to produce it.
3. **Result-oriented PSS:** selling a result or capability instead of a product (e.g. Web information replacing directories, selling laundered clothes instead of a washing machine). Companies offer a customized mix of services where the producer maintains ownership of the product and the customer pays only for the provision of agreed results.

All three types of PSS solution satisfy customer needs through a combination of products and services that are systemized to deliver the desired utility or function. However, the results-orientated model is more sophisticated and represents the most popular interpretation of the features of a PSS. Hence, this leads us to summarize:

3.3.1 Finding 3

A PSS is a special case in servitization, which values asset performance or utilization rather than ownership, and achieves differentiation through the integration of product and services that provide value in use to the customer.

3.4 Applications of PSSs

There are many descriptions of PSS applications in the literature. Goedkoop *et al.* [2] provides almost 150 examples of separate PSS. These were captured during a questionnaire-based survey and are very diverse. They range from the provision of ecologically grown vegetables, to a description of how DuPont Flooring Systems (USA) has shifted focus from selling floor coverings to providing total servicing to customers: installation, tailored maintenance, take-back, and recycling [2]. Similarly, Mont [3, 4] gives 35 examples of PSS initiatives categorized from 'take back/remanufacture' (Xerox Corporation) to 'Car Sharing' (in Leiden, Netherlands). More specific and detailed case studies of PSS-associated applications are provided by, for example, the Centre for Sustainable Design [26], Luiten *et al.* [15], Morelli [14], Brandsotter *et al.* [16], Manzini *et al.* [7], Oman [13], and Wong [10].

Some of the more successful examples of PSS, as highlighted in the literature, are Parkersell, Xerox, and Cannon (see Table 2). Parkersell (a UK lighting company) offer an integrated lighting system solution for Sainsbury's [17], while Xerox, Canon, and Océ are seen as PSS leaders with their 'pay per copy' lease and take back programmes. When selecting

Table 2 Examples of successful Product Service-Systems

Organization	Description	Link
Xerox International	Products are sold guaranteeing fixed price per copy from products/processes designed for remanufacturing.	http://www.xerox.com
Parkersell (UK)	Parkersell developed a product service integrated lighting system solution for Sainsbury more efficient in life cycle costing and environmental improvement.	http://www.pss-info.com
Castrol Inc. (USA)	Lubricant service packages reducing lubricant consumption. Profit from cost saving not consumption.	http://castrolindustrial.com
Eastern Energy (UK)	Not just energy. Energy management, consumption and process monitoring and utility awareness and training.	http://www.eastern-energy.co.uk
Electrolux (Sweden)	Initial fee then pay per wash from remotely monitored energy efficient machine and Launderette system solutions including maintenance, repair and finance services.	http://www.corporate.electrolux.com
Mobility (Switzerland)	Vehicle sharing group – 1400 cars, 850 locations, 350 communities. Less than 1500 km/saves money.	http://www.mobility.ch

their successful cases, authors dealing with PSS appear to be attracted by the novelty, completeness, and environmental benefits of schemes, rather than in-depth assessments of implications to competitiveness. Hence, the TotalCare package offered by Rolls-Royce plc [10] is rarely cited, even though this now accounts for a significant portion of gas turbine business for this organization in 2005/6. This exploration of the applications of PSS leads the authors to summarize:

3.4.1 Finding 4

There is a diverse range of PSS examples in the literature, apparently demonstrating economic success but tending to emphasize the environmental and social gains.

3.5 The benefits of a PSS

The approach most frequently taken in the literature is to give a short description of a PSS, and then describe the benefits experienced [e.g. 13, 24, 26]. These mini cases tend to be qualitative.

For the customer, a PSS is seen to provide value through more customization and higher quality (e.g. improved machine availability for a machine tool within a specific factory context). The service component, being flexible, can also deliver new functionality better to suit customer needs [24] and is often described as removing administrative or monitoring tasks away from the customer and back to the manufacturer. For most reported PSS cases, the customer receives value in a form that is close to current needs; while innovative forms of value are suggested as being possible [7, 27], few real-life examples are presented.

For traditional manufacturers, PSS is claimed to provide strategic market opportunities [2, 6, 7] and an alternative to standardization and mass production. The fundamental business benefit of a PSS is an

improvement in total value for the customer through increasing service elements. Competitive edge is enhanced as, for example, a service element that is not easy to copy and facilitate, communicates information about the product-service package [3]. The environment also benefits from PSS since a producer becomes more responsible for its products-services through take-back, recycling, and refurbishment – reducing waste through the product's life [6]. For manufacturers, the potential to use their technical knowledge to find ways to deliver same or better value-in-use while using less energy or material is said to offer the potential to reduce cost (as well as environmental impact). In addressing the issue of the role of public policy in the advancement of PSS, Mont [12] states that the PSS approach to business has potential benefits for customers, producers, governments, and the environment.

For a State and the global environment, adoption of PSS can lead to reduced resource use and reduced waste generated since fewer products are manufactured using fewer materials per use [21]. Similarly, successful PSS applications can, through the increase in sales and service activities, offset the loss of jobs in traditional manufacturing [6, 7]; and as public pressure on environmental issues grows, the widespread promotion and adoption of PSS is favoured by government bodies. This is demonstrated by the interest shown in PSS by Sweden and the Netherlands who tend to lead in the adoption of environmentally sustainable business. The first work in this area by Goedkoop *et al.* [2], for example, was supported by the Dutch Ministries of Economics and the Environment. This exploration of the benefits leads the authors to summarize:

3.5.1 Finding 5

There are a wide range of benefits of a PSS; to the producer it means an offering of higher value that is more easily differentiated, to the customer it is a

release from the responsibilities of asset ownership, and to society at large a more sustainable approach to business.

3.6 Barriers to the adoption of a PSS

The adoption of a PSS strategy brings with it significant cultural and corporate challenges. The majority of authors (e.g. Goedkoop *et al.* [2], Manzini *et al.* [7], Mont [6] and UNEP [21]) see the main barrier to the adoption of a PSS as the cultural shift necessary, for a consumer to place value on having a need met as opposed to owning a product. Wong [10] argues that the success of a PSS solution in the consumer market is highly dependent on being sensitive to the culture in which it will operate. He notes that PSS solutions have been more readily accepted in the communal societies of Scandinavia, the Netherlands, and Switzerland.

Within those organizations that might desire to design, make, and deliver a PSS, the significant change in the system of gaining profit could deter producers from employing the concept [2], firstly through limited experience in pricing such an offering, secondly through fear of absorbing risks that were previously assumed by customers, and thirdly through lack of experience in structuring an organization to be competent at designing, making, and delivering a PSS. Likewise, an effective PSS is likely to be more complex for a manufacturing organization than the existing way of delivering functionality through the provision of a product alone. This will require changes to be undertaken at the functional and systemic level [23]. Hence, this leads the authors to summarize:

3.6.1 Finding 6

The principal barriers to the adoption of PSS are positioned at both sides of the dyad: consumers may not be enthusiastic about ownerless consumption, and the manufacturers may be concerned with pricing, absorbing risks and shifts in the organization, which requires time and money to facilitate

3.7 Features in the effective design of a PSS

A PSS must be designed, made, and delivered on a case-by-case basis and viewed from the client's perspective.

When designing a PSS, a company must move from 'product thinking' to 'system thinking', and breakdown the 'business as usual' attitude [7]. In particular, PSS requires manufacturers and service providers to extend their involvement and responsibility from making a product available to purchase to phases of the life cycle that are usually outside the buyer-seller relationship (e.g. maintenance, take-back, recovery of materials, re-use, refurbishment, and remanufacture) [7]. Frequently, organizations need to change their

traditional structures to accommodate their involvement with the customer and other partner/supplier organizations in the infrastructure. These changes modify the relationships between business functions in the organization and increase the demand for 'human capital' [6]. Outside the focal organization, several stakeholders may need to be involved in the process, as competitive and sustainable PSS solutions can rarely be provided by a single company [15].

The relationship between the customer and the company plays a key role in the design of an effective PSS. Early involvement with the customer is essential to achieve a solution that responds to customer wants and needs [3, 7, 15]. Indeed, Rocchi [27] and Luiten [15] both argue that users should be treated as innovators, emphasizing a shift to what they term as a value co-creation process, whereby professional customers and end-users play an organized and important role in designing. Hence, the authors summarize that:

3.7.1 Finding 7

A successful PSS needs to be designed at the systemic level from the client perspective and requires early involvement with the customer and changes in the organizational structures of the provider.

3.8 Tools and methodologies for designing a PSS

There are a variety of tools and methodologies outlined in the literature. For example, the *MEPSS Handbook* [22] offers a methodology and toolkit for developing a PSS model. This was created between 2001 and 2004 with support from the European Commission under the Fifth Framework Programme. Partners included PwC Netherlands, Pre Holland and the Centre for Sustainable Design, UK. Similarly, Mont [3] proposes that a PSS may be created in a step-by-step fashion based on the Deming cycle; Aurich *et al.* [26] develop a process for the systematic design of technical services supporting a product; and Goedkoop *et al.* [2] offer a four-axis model for auditing a PSS. Many of these methods are presented by illustrating their intended use. For example, Goedkoop *et al.* [2] gives examples of his approach against ten proposed product systems. Exceptions are authors such as Aurich *et al.* [19] who test their approach with a case study. Nevertheless, in-depth and critical evaluation of these methods tends to be limited.

Various methodologies are presented that are tailored to specific projects (e.g. [15, 16, 14, 25]). There is a strong generic flavour to these methodologies with many having a clear heritage in Concurrent Engineering and Lean Product development methodologies [28] i.e. identification of customer value, early involvement of the customer in the system design, effective communication, information sharing, and

continuous improvement. It is argued by some authors that these may need further development to facilitate business wide implementation of PSS. However, Mont [29] in the editorial for the special edition of the *Journal of Cleaner Production* in 2006 considers the development of generic methodologies as unlikely and unnecessary. This exploration of the literature on tools and methodologies leads the authors to summarize:

3.8.1 Finding 8

A range of tools and methodologies exist for designing PSS; however, these tend to lack a critical and in-depth evaluation of their performance in practice; they are typically a subtle development of more conventional processes; and there is a lack of evidence for the completeness of the set of tools and methods proposed.

3.9 Future research challenges in the PSS literature

The existing literature on PSS explicitly identifies future challenges in terms of research topic and process.

With regards to topic, tools need to be developed which enable the modelling of PSS [6, 11]. Similarly, assessment tools are also required that reveal when a PSS has a clear environmental benefit and so provide useful information on which a customer can base decisions [21]. More quantitative methods are called for, to help organizations to understand the perceived value that a potential customer may hold, and to evaluate the level of service that is required [20]. Understanding the management of the transition, as an organization moves from a traditional product-sale model to a PSS model, is also a growing subject in the literature [24]. Finally, it is recognized that there has been insufficient work carried out to capture and present successful PSS applications.

In terms of approach, the greatest reported challenge is to engage relevant stakeholders in the process of research, evaluation, and testing at both theoretical and practical levels [23]. In industry, this means that long-term and integrated testing of PSS practice is needed to help to develop theories, methodologies, and operational solutions [12]. In academe, many argue for a quantum jump in academic rigour in the design of tools/methodologies, with much better links to case studies to allow rigorous 'cross-case' analyses. This leads the authors to summarize:

3.9.1 Finding 9

The PSS literature highlights that in-depth and rigorous research is needed to develop models, methods, and theories. More widespread adoption of the PSS

concept needs better understanding of PSS practices, of methods to assess value, and of organizational transitions.

4 CONCLUDING REMARKS

The aim of the research presented here has been to identify, interpret, and summarize the literature currently available on PSS and nine key findings have been established. In summary, a PSS is an integrated product and service offering that delivers value in use. This concept originated in Northern Europe in the late 1990s and, to date, most contributors have been academics from environmental and social sciences. There are a diverse range of PSS examples in the literature with some demonstrating economic success but most tending to emphasize significant environmental and social gains.

There are, however, some key barriers to the adoption of PSS; for instance, consumers may not be enthusiastic about ownerless consumption. Similarly, while some methods and practices are proposed for designing and operating PSSs, these tend to lack the pedigree that is formed through careful evaluation in practice. The findings confirm that PSS solutions have the potential for decoupling environmental pressure from economic growth by focusing on asset use rather than on asset ownership. However, the lack of regulatory drivers, and the fact that in developed countries consumers may not be excited about ownerless consumption, is perceived by companies as potential barriers to the adoption of a PSS strategy. The principal issues concern the lack of well-developed tools and methodologies that can provide manufacturers with a business-wide guide for the implementation of PSSs. Here, of particular benefit would be a geographical widening of the research community and an increased contribution from authors in Manufacturing, Engineering, Design, and Management.

The findings and issues raised in this paper provide a useful platform on which to base more in-depth research. PSSs and servitization are both concepts of significant potential value to manufacturers in the UK. Both provide routes for companies to move up the value chain and exploit higher value business activities. This message is reinforced through the successes of companies such as RR with TotalCare. However, these concepts should not be considered to be universally applicable. While it is difficult to imagine that any manufacturer can succeed without offering some services (e.g. after-sales support, training, finance) these need not form the basis of a competitive strategy. Success can also be achieved through excelling at either Product leadership or operational excellence.

For those manufacturers that do see the provision of services as key to their future, there are still significant challenges to be faced. To be both effective and efficient, manufacturers need, for example, to be able to understand how their customers will value their services. Similarly, they will need to be able to configure their products, technologies, operations, and supply chain to support this value offering. Yet, as this paper has gone some way to demonstrate, there is little guidance available for manufacturers in this situation. Indeed, the following research questions can be posed:

1. How are servitized organizations and PSSs designed?
2. How are servitized organizations and PSSs built and delivered?
3. How are servitized organizations and PSSs sustained by the network?
4. How can the value-in-use delivered by PSSs be assessed?
5. How can 'traditional' manufacturing firms make the transition to servitized organizations?

The authors' own research will now set out to address these and in doing so will undoubtedly raise other questions. They look forward to reporting both these and their progress in future articles.

REFERENCES

- Q2 1 **Hewitt, P.** *The Government's Manufacturing Strategy*, April 2002, 4.
- Q3 2 **Goedkoop, M. et al.** Product Service-Systems, ecological and economic basics. Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ), 1999.
- 3 **Mont, O.** Product Service-Systems. Final report. 2000 (IIIEE, Lund University).
- 4 **Meijkamp, R.** Changing consumer behaviour through eco-efficient services. An empirical study of car sharing in the Netherlands. Delft University of Technology, 2000, p. 296.
- 5 **Manzini, E. and Vezzoli, C.** A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize. *J. Cleaner Prod.*, 2003, **11**.
- 6 **Mont, O.** Clarifying the concept of product service-systems. *J. Cleaner Prod.*, June, 2002, **10**(3), 237–245.
- 7 **Manzini, E., Vezzoli, C., and Clark, G.** Product service-systems: using an existing concept as a new approach to sustainability. *J. Des. Res.*, 2001, **1**(2).
- 8 **Mont, O.** Introducing and developing a PSS in Sweden, 2001 (IIIEE, Lund University) 6.
- 9 **Ehrenfeld, J.** Designing 'sustainable' product service-systems. In Proceedings of the Second International Symposium on *Environmentally Conscious Design and Inverse Manufacturing*, 2001, pp. 12–23.
- 10 **Wong, M.** Implementation of innovative product service-systems in the consumer goods industry. PhD Thesis, Cambridge University, 2004.
- 11 **Tomiyama, T.** Service engineering to intensify service contents in product life cycles. In Proceedings of the Second International Symposium on *Environmentally Conscious Design and Inverse Manufacturing*, 2001, pp. 613–18.
- 12 **Mont, O. and Lindhqvist, T.** The role of public policy in advancement of product service systems. Special paper. *J. Cleaner Prod.*, December, 2003, **11**(8), 905–914.
- 13 **Oman, I.** Product Service-Systems and their impacts on sustainable development – a multi-criteria evaluation for Austrian Companies. *Frontiers*, 2003.
- 14 **Morelli, N.** (School of Architecture and Design, Aalborg University) Product service-systems, a perspective shift for designers: a case study – The design of a telecentre. *Des. Stud.*, January, 2003, **24**(1), 73–99.
- 15 **Luiten, H., Knot, M., and van der Horst, T.** Sustainable product service-systems: the Kathalys method. In Proceedings of the Second International Symposium on *Environmentally Conscious Design and Inverse Manufacturing*, 2001, pp. 190–197.
- 16 **Brandstotter, M.** (Austrian Society for Syst. Eng. & Autom., Xx, Austria), **Haberl, M., Knoth, R., Kopacek, B., and Kopacek, P.** IT on demand – towards an environmental conscious service system for Vienna (AT). 2003. In the Third International Symposium on *Environmentally Conscious Design and Inverse Manufacturing – EcoDesign'03* (IEEE Cat. No.03EX895), 2003, pp. 799–802.
- 17 **Parkersell** Case Study. Methodology for Product Service Systems (MEPSS) 2004.
- 18 **ELIMA** Report. Environmental life cycle information management and acquisition for consumer products, 2005.
- 19 **Aurich, J., Fuchs, C., and Wagenknechy, C.** Life cycle oriented design of technical product service-systems. *J. Cleaner Prod.*, 2006, **14**(17), 1480–1494.
- 20 **Tomiyama, T. et al.** AAA Note on Service design Methodology. In Proceedings of the DETC, 2004. Q4
- 21 **UNEP.** *The Role of PSS in a sustainable society*, 2001. Q5
- 22 **MEPSS.** *Handbook*, 2004. Q6
- 23 **Williams, A.** Product service-systems in the automotive industry: a case for micro-factory retailing. *J. Cleaner Prod.*, 2006, **14**, 172–184.
- 24 **Cook, M., Bhamra, T., and Lemon, M.** The transfer and application of Product Service-systems: from academia to UK manufacturing firms. *J. Cleaner Prod.*, 2006, **14**(17), 1455–1465.
- 25 **Maxwell, I. and van der Vorst, R.** Developing sustainable products and services. *J. Cleaner Prod.*, 2003, **11**, 883–895.
- 26 **Centre for Sustainable Design.** Sustainable service-systems (3S). Transition towards sustainability. In Sixth International Conference, 2002. Q7
- 27 **Rocchi, S.** Enhancing sustainable innovation by design. PhD Thesis, Erasmus University, Rotterdam, 2005.
- 28 **Baines, T. S., Lightfoot, H. W., Williams, G., and Greenough, R.** State-of-the-art in lean design engineering; a literature review on white collar lean. *Int. J. Mech. Engng* (forthcoming).
- 29 **Mont, O.** PSS – a review of achievements and refining the research agenda. Editorial. *J. Cleaner Prod.*, **14**(17), 2006.

BIBLIOGRAPHY

- 1 **Besch, K.** Product service-systems for office furniture: barriers and opportunities on the European market (Intl. Inst. Indust. Environ. Econ., Lund University) *J. Cleaner Prod.*, August/September, 2005, **13**(10–11).
- Q8 2 ERSCP2004 Workshop: Product service-systems – sustainable product service-systems. Summary brochure SUSPRONET, 2004.
- 3 **Hirschl et al.** New concepts in product use for sustainable consumption. *J. Cleaner Prod.*, 2003, **11**.
- 4 **Kimura, F.** Lifecycle design for inverse manufacturing. In Proceedings of the IEEE International Symposium on *Environmentally Conscious Design and Inverse Manufacturing*. IEEE, February 1999, p. 997.
- Q9 5 Life cycle approaches to sustainable consumption. Workshop Proceedings 2002.
- 6 **Mont, O.** Product Service-Systems: panacea or myth? PhD Thesis, Lund University, Sweden, 2004.
- 7 **Mont, O.** Editorial for the special issue of the *Journal of Cleaner Production* on Product Service-Systems. *J. Cleaner Prod.*, December, 2003, **11**(8), 815–817.
- Q10 8 **Magretta.** Growth through global sustainability. *Harvard Bus. Rev.*, 1997.
- 9 **Michaelis, L.** The role of business in sustainable consumption. *J. Cleaner Prod.*, 2003, **11**.
- 10 **Shehab, E. M** and **Roy, R.** Product service-systems: issues and challenges. In the Fourth International Conference on *Manufacturing Research* (ICMR 2006). John Moores University, Liverpool, 5th–7th September 2006.
- 11 **Mont, O.** What is behind meagre attempts to sustainable consumption? Institutional and product-service systems perspective. In Proceedings of the International Workshop, *Driving forces and barriers to sustainable consumption*, Leeds, UK, 2004.
- 12 **Wise and Baumgartner.** Go downstream: the new profit imperative in manufacturing. *Harvard Bus. Rev.*, September–October 1999. Q11
- 13 **Auernhammer, K.** and **Stabe, M.** Integrated development of products and services. Knowledge and Technology Integration in Production and Services. IFIP TC5/WG5.3. In Proceedings of the Fifth IEEE/IFIP International Conference on *Information Technology for Balanced Automation Systems in Manufacturing and Services* (BASYS'02), 2002, pp. 367–374. Q12
- 14 **Halliday, J.** Sustainable growth the DuPont way. *Harvard Bus. Rev.*, 2001.
- 15 **Hart, S.** Beyond greening: strategies for a sustainable world. *Harvard Bus. rev.*, 1997.
- 16 **Johnston, R.** Operations: from factory to service management. *Int. J. Serv. Ind. Mgmt*, 1994, **5**(1).
- 17 **Quinn, B., Doorley, B., and Paquette, P.** Beyond products: service-based strategies. *Harvard Bus. Rev.*, March–April, 1990.
- 18 SusPro Net Report. Sustainable product service-systems, 2004. Q13
- 19 UNEP. Promoting a life cycle approach. Seminar on cleaner production – Seventh High-Level Conference, 2002. Q14
- 20 Factor 10 Club. Statement to Government and business leaders (1997). (<http://www.baltic-region.net/factor10.htm>) Q15
- 21 **Manzini, E., Collina, L., and Evans, S.** Solutions oriented partnership, 2004 (Cranfield Press, Bedfordshire).

TO: CORRESPONDING AUTHOR

AUTHOR QUERIES - TO BE ANSWERED BY THE AUTHOR

The following queries have arisen during the typesetting of your manuscript. Please answer these queries by marking the required corrections at the appropriate point in the text.

Query number	Query Details	
Q1	No keywords?	
Q2	Publisher?	
Q3	et al/please provide details	
Q4	et al/please provide details	
Q5	Please provide more details. Publisher?	
Q6	Please provide more details. Publisher?	
Q7	Please provide more details. Place/Pages?	
Q8	et al/please provide details	
Q9	Please provide more details.	
Q10	Initial of Authors' first name?	
Q11	Initial of Authors' first name?	
Q12	Is the source a journal?	
Q13	Please provide more details. Publisher?	
Q14	Please provide more details. Place?	
Q15	Last date of access?	