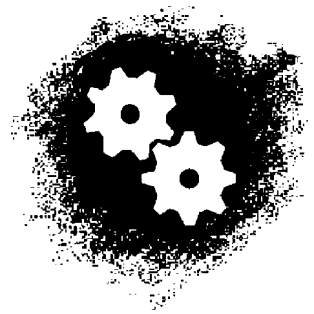


EIGHT TYPES OF PRODUCT-SERVICE SYSTEM: EIGHT WAYS TO SUSTAINABILITY? EXPERIENCES FROM SUSPRONET



Arnold Tukker*

TNO Institute of Strategy, Technology and Policy, The Netherlands

Function-oriented business models or product-service systems (PSSs) are often seen as an excellent means for achieving 'factor 4'. SusProNet, an EU network on PSSs, showed a more complicated reality. At least eight different types of PSS exist, with quite diverging economic and environmental characteristics. The *economic* potential of each type was evaluated in terms of (i) tangible and intangible value for the user, (ii) tangible costs and risk premium for the provider, (iii) capital/investment needs and (iv) issues such as the providers' position in the value chain and client relations. The *environmental* potential was evaluated by checking the relevance of certain impact reduction mechanisms (e.g. more intensive use of capital goods, inherent incentives for sustainable user and provider behaviour etc.). Most PSS types will result in marginal environmental

improvements at best. The exception is the PSS type known as functional results, but here liability and risk premium issues, amongst others, need a solution. Copyright © 2004 John Wiley & Sons, Ltd and ERP Environment.

Received 4 March 2004
Revised 22 March 2004
Accepted 14 April 2004

INTRODUCTION

A product-service system (PSS) can be defined as consisting of 'tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs' (see e.g. Tischner *et al.*, 2002).¹ Many see PSSs as an excellent vehicle to enhance competitiveness and to foster sustainability simultaneously. In many markets products have become equally well performing commodities. Here, the basis of competition has shifted from functional per-

* Correspondence to: Arnold Tukker, Programme Manager Sustainable Innovation, TNO Institute of Strategy, Technology and Policy, P.O. Box 6030, 2600 JA Delft, The Netherlands
E-mail: Tukker@stb.tno.nl

¹ Though the term PSS is now fairly well known in circles of (sustainability) researchers and also widely used in the EU's Fifth Framework Research Program (FP5), business usually use terms such as 'solution development' or 'functional sales'.



formance, via fitness for use, to price (see e.g. Montalvo Corral, 2002, p. 20). A PSS business model allows firms to create new sources of added value and competitiveness, since they

- fulfil client needs in an integrated and customized way, hence allowing clients to concentrate on core activities,²
- can build unique relationships with clients, enhancing customer loyalty, and
- can probably innovate faster since they follow their client needs better.

In theory, the 'result-oriented' PSS has the particular potential to overcome all kinds of split incentive concerning the environment (UNEP, 2002, p. 9). As a result, it would be in the interest of both producer and consumer to minimize life-cycle costs, and hence the use of consumables in the use phase.³ Furthermore, if one tries to design a need fulfilment system that really takes final consumer needs (rather than the product fulfilling the need) as a starting point, the freedom to design systems with factor 4–10 sustainability improvements is much higher.

These benefits prompted the EU to invest heavily in PSS development in its Fifth Framework Programme, partly by setting up SusProNet (the acronym for the Sustainable Product Development Network).⁴ However, SusProNet's analyses thus far do not confirm that PSSs are a win-win strategy. For many successful PSSs it is not clear whether they are sustainable, and many purpose-designed

sustainable PSSs (pay per wash, sustainable grocery conscriptions etc.) have failed, or cling on to a marginal existence in the market.⁵ So why is this? In our view, analyses of PSSs often forget to focus on the following points.

- A major reason for being in business is to create added value. Industry's new business developers will embark on PSS models, when that is the key to competitiveness and value creation, but will adopt other models when that better helps to beat competition. The first question to be answered in this paper is *which factors determine whether a PSS business model is the best way to create value added?*
- Sustainability is about fulfilling needs with minimal material use and emissions. The sustainability of PSSs depends on whether a PSS as such is less material intensive, and whether actors in the chain feel incentives to lower material intensity even more. The second question to be answered is *which factors determine whether a PSS business model per se generates less material flows and emissions than the competing product oriented models, and thus provides incentives for sustainable behaviour?*

This paper will first discuss what a PSS is, and present *eight* archetypical PSS business models. It will then present a theory about value creation and a conceptual model about the relation between PSSs and sustainability. Using these two models, the market potential and sustainability potential of the archetypical PSS models will be evaluated. The interest lying within the overall analysis is then to identify situations where both the business drivers and the sustainability incentives for PSS are mutually reinforcing.

² For instance: an electronics firm does not want to devote energy and management time to running their company restaurant, and hence outsource it to a caterer. Many consumers with busy jobs no longer bother buying potatoes, groceries and meat, and cooking their own meal, but rely on convenience food that can be served in a few minutes.

³ This is not so much an issue for someone who just sells a product: costs in the use phase are hidden and in a commodity market competition is on (lowest) sales price – if needs be by a poor design that results in high use phase costs.

⁴ The network is co-ordinated by TNO, econcept, VITO, CfSD, INETI and O2, and has some 30, mostly industrial, organizations as direct participants. Furthermore, some 100+ other professionals are involved. For more information, see www.suspronet.org.

⁵ It is maybe not totally coincidental that such 'idealistic' PSSs are mainly proposed by university researchers with hardly any first hand experience in business development in companies. Kazazian (2002) tried to deal with this by asking for comments on his sustainable business ideas from real-world companies. Unfortunately, in most cases the latter were quick to point out the reasons why Kazazian's ideas were not attractive businesses for them.

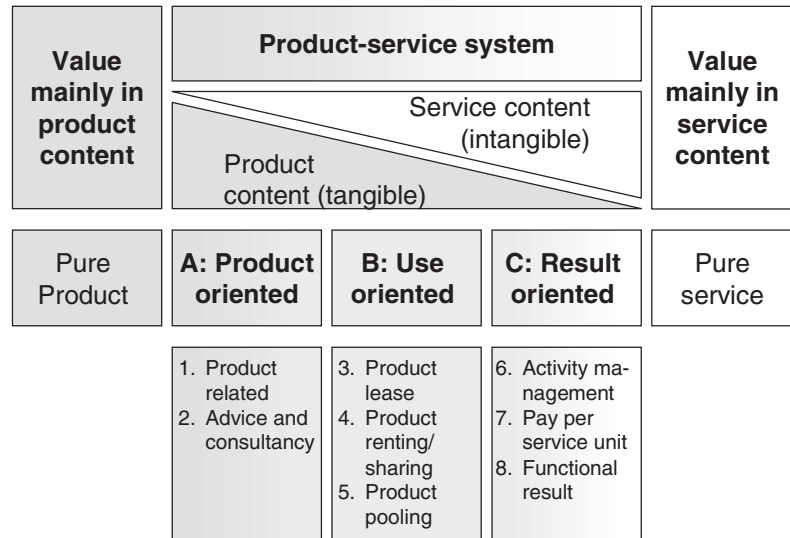


Figure 1. Main and subcategories of PSS

PRODUCT-SERVICE SYSTEMS: EIGHT ARCHETYPICAL MODELS

Various classifications of PSS have been proposed (see e.g. Behrend *et al.*, 2003; Brezet *et al.*, 2001; Zaring *et al.*, 2001). Most classifications make a distinction between three main categories of PSS. These are shown in Figure 1.

- The first main category is *product-oriented services*. Here, the business model is still mainly geared towards sales of products, but some extra services are added.
- The second main category is *use-oriented services*. Here, the traditional product still plays a central role, but the business model is not geared towards selling products. The product stays in ownership with the provider, and is made available in a different form, and sometimes shared by a number of users.
- The last main category is *result-oriented services*. Here, the client and provider in principle agree on a result, and there is no pre-determined product involved.

However, each category itself includes PSSs with quite different economic and environmental characteristics. Elaborating on a typol-

ogy developed in a Dutch PSS manual (Tukker and van Halen, 2003), it is possible to identify the following more specific PSS types.

Product-oriented services

- *Product-related service*. In this case, the provider not only sells a product, but also offers services that are needed during the use phase of the product. This can imply, for example, a maintenance contract, a financing scheme or the supply of consumables, but also a take-back agreement when the product reaches its end of life.
- *Advice and consultancy*. Here, in relation to the product sold, the provider gives advice on its most efficient use. This can include, for example, advice on the organizational structure of the team using the product, or optimizing the logistics in a factory where the product is used as a production unit.

Use-oriented services

- *Product lease*. Here, the product does not shift in ownership. The provider has ownership, and is also often responsible for maintenance, repair and control. The lessee pays



a regular fee for the use of the product; in this case normally he/she has unlimited and individual access to the leased product.

- *Product renting or sharing.* Here also, the product in general is owned by a provider, who is also responsible for maintenance, repair and control. The user pays for the use of the product. The main difference to product leasing is, however, that the user does not have unlimited and individual access; others can use the product at other times. The same product is *sequentially* used by different users.
- *Product pooling.* This greatly resembles product renting or sharing. However, here there is a *simultaneous use* of the product.

Result-oriented services

- *Activity management/outsourcing.* Here a part of an activity of a company is outsourced to a third party. Since most of the outsourcing contracts include performance indicators to control the quality of the outsourced service, they are grouped in this paper under result-oriented services. However, in many cases the way in which the activity is performed does not shift dramatically. This is reflected by the typical examples for this type, which include, for example, the outsourcing of catering and office cleaning that is now a commonplace in most companies.
- *Pay per service unit.* This category contains a number of other classical PSS examples. The PSS still has a fairly common product as a basis, but the user no longer buys the product, only the *output* of the product according to the level of use. Well known examples in this category include the pay-per-print formulas now adopted by most copier producers. Following this formula, the copier producer takes over all activities that are needed to keep a copying function in an office available (i.e. paper and toner supply, maintenance, repair and replacement of the copier when appropriate).

- *Functional result.* Here, the provider agrees with the client the delivery of a result. This category is used in this article, in contrast to activity management/outsourcing, for a functional result in rather abstract terms, which is not directly related to a specific technological system. The provider is, in principle, completely free as to how to deliver the result. Typical examples of this form of PSS are companies who offer to deliver a specified 'pleasant climate' in offices rather than gas or cooling equipment, or companies who promise farmers a maximum harvest loss rather than selling pesticides.

Going from the first to the last of these eight types of PSS, the reliance on the product as the core component of the PSS decreases, and the need of a client is formulated in more abstract terms. Every time the provider has a little more freedom in fulfilling the true final need of the client. However, abstract demands are often difficult to translate into concrete (quality performance) indicators, which makes it difficult for the providers to determine what they have to supply, and difficult for the clients to know whether they have got what they asked for.

THE BUSINESS CASE FOR PSSs: FACTORS INFLUENCING ADDED VALUE AND INNOVATION POTENTIAL

This section deals with the first key question of this paper: *which factors determine whether a PSS business model is the best way to create value added?*⁶ To address this question, the factors

⁶ In this I assume a fairly rational approach of firms to business. Of course sometimes bounded rationalities and existing heuristics will prevent a firm from seeing easily achievable win-wins (cf. Simon, 1957; Lindblom, 1959), but usually the pros and cons of embarking on a specific business model are well analysed, and preferences for incremental innovation trajectories all too often can be explained as rational and cost-effective building upon previous investments in fixed assets, equipment, human resources etc. (cf. Dosi, 1982).



that determine whether added value is at stake or not are analysed, and the situation is then reviewed for each PSS business model.

Value elements in PSS

The ability to create and capture sustained added value (often referred to as shareholder value) is often seen as the key measure of success of business. In this paper I use the concept of *economic value added* (or EVA) as proposed by Stewart (1991). He defines EVA as

A fundamental measure of corporate performance, it is computed by taking the spread between the return on capital and the cost of capital, and multiplying by the capital outstanding at the beginning of the year [...]. It is the residual income that remains after operating profits cover a full and fair return on capital (i.e. the cost of capital). In theory, a company's market value added at a point in time is equal to the discounted present value of all EVA it can be expected to generate in the future [...].

On the basis of the definition above, a number of key elements can be distinguished:

- market value of the PSS (tangible and intangible);
- production costs of the PSS (including risk premium aspects);
- investment needs/capital needs for PSS production and
- the ability to capture the value present in the value chain, now and in the future.

The difference between the first and second elements, in combination with the fourth, determines the operating profits of the PSS provider (network) – now, and in the future. The third element indicates whether a need for high or low capital is a factor in determining such profits. This is highly relevant, since if the same profit can be made with lower capital needs this leads to a higher EVA.

The four elements described above need to be discussed in more detail. The aim is to come up with a set of criteria that helps to evaluate whether it is better to put a PSS on the market, compared with a product.⁷

Market value of the PSS (tangible and intangible)

This element includes the following aspects.

- Tangible or objective value for the consumer (e.g. resources, time input and cost of capital saved).
- Intangible or subjective value for the consumer (e.g. additional, 'priceless' experiences).

Tangible or objective value is a fairly straightforward concept. A customer who has the choice between buying a product, or using a PSS, can start to make a rational calculation about what the product actually costs, including all kinds of 'hidden' cost, and that is in principle the maximum price he/she would like to pay for a competing PSS. For instance, in the concept of chemical manufacturing services the PSS provider not only sells chemicals, but takes over specific handling and management tasks for the client. This saves the client human resources, management time and maybe even space, which often costs five to ten times more than the chemicals themselves (Votta, 2003). Intangible or subjective value is a little less straightforward as a concept, but is currently the key to success or failure of many products and services in the consumer market. In an affluent (Western) society consumers can generally take basic Maslowian needs such as food, shelter and safety for granted, and will be more geared toward the realization of higher needs such as affiliation, love, esteem and self-realization. Authors such as Pine and

⁷ The comparison is done per functional amount product and PSS. This is probably an oversimplification, since it is likely that success on the market will differ and hence market volume too. In principle, one could try to expand the line of thought developed here into a quantitative evaluation model, but that is an endeavour I leave for another time.



Gilmore (1999) and LaSalle and Britton (2003) argue that society is shifting to an *experience economy* (see also Grinyer, 2003).⁸ The trick then becomes to satisfy needs on these higher levels in conjunction with the offer of a material artefact: 'turning ordinary products into extraordinary experiences'.⁹ By creating such intangible added value, the provider makes the client willing to pay more than would be justified on the basis of 'rational' calculation. This allows the provider to charge more, but the user is forced to diminish other expenditures to pay the extra.

Production costs of the PSS (including risk premium aspects)

This element includes the following aspects.

- Traditional 'tangible' production costs (e.g. resources, time input and cost of capital used).
- Risk premium/uncertainty related to the solution.

Traditional tangible production costs often mirror the tangible or objective value for the consumer discussed above. Often, servicing implies that activities formerly performed by the user are now performed by the provider. This makes sense if the tangible added value of the PSS for the user is higher than the (extra) production costs for the provider, or if a cost deficit is more than compensated for by the intangible added value that the user attributes to the PSS.¹⁰ Risk premium or uncertainty is

⁸ See, for example, the interesting overview of Vlek *et al.* (1999), who discuss need hierarchies in the context of sustainable consumption. Not totally coincidentally, LaSalle and Britton argue that human beings do not desire goods in themselves, but the benefits goods provide at the higher levels at which human beings operate, such as physical, emotional, intellectual and spiritual.

⁹ As LaSalle and Britton subtitled their book. The main title, *Priceless*, was taken from a Mastercard commercial, which goes roughly as this: *Matches: 10 cts. Candles: \$8. Relaxation in the atmosphere created: priceless.*

¹⁰ A change from products to PSS might imply a shift between cost categories (e.g. lower costs for capital goods since they can be more intensively used, but extra costs due to more complicated billing systems and more service personnel etc.).

relevant for (specifically) result-oriented PSSs. By promising a *result*, the provider often faces difficulties in predicting and controlling risks, uncertainties and responsibilities that otherwise were the problem of the user. For instance, if a company sells pesticides and gives advice on how to use them, the farmer bears the full risk of success of crop growth. If the provider promises a result such as an $x\%$ reduction in loss of crop due to pests, a hefty penalty might have to be paid if the provider fails.¹¹ If such liabilities cannot be controlled, the provider should either refrain from such a PSS or include a (probably prohibitive) high-risk premium in its cost price.

Inherent capital needs plus investment needs for PSS production

This element includes the following aspects.

- The inherent capital base needed to produce the solution.
- Any additional 'transition' investments needed to create the system that produces the solution.

The first aspect in principle concerns a straightforward comparative calculation of the capital needs of the technical and organizational structure of the product and PSS providing systems. There can be important differences between PSS types. For instance, a company leasing cars needs one car for each client. A company operating a car pooling system can have considerably fewer cars for the same client pool, and hence needs to invest considerably less. Additional transition investments relate to the assumption that in most cases companies are currently quite product oriented. They have to invest in infrastructures and relationships to be able to provide a PSS. Such transition costs can be of intangible nature, such as the problems

¹¹ This is an example where one can define still meaningful and quite tangible indicators measuring success. If such indicators cannot be found, putting a result-oriented PSS on the market becomes virtually impossible, or if one does, a source of quarrel between provider and client.



involved in breaking up a relationship with a preferred supplier. In principle such transition costs have to be treated as investments that therefore tie in capital.

The ability to capture value present in the value chain, now and in the future

This element includes the following aspects.

- Strategic position in the value network: ability to capture value.
- Sustained low barriers for access to the service and a contribution to client loyalty.
- Contribution to a comparatively high speed of innovation.

The first aspect has been stressed by Porter (1985) amongst others. The creation of (tangible and intangible) value alone is not sufficient. The PSS provider (network) should be powerful enough to *capture* this value as well. To do this, the provider network has to create a quasi-monopoly by covering the essential parts of the delivery or production system, i.e. the parts that cannot easily be copied or performed by other parties (e.g. unique relationships with clients, unique technologies, etc.).¹² The second aspect is often associated with user-oriented and result-oriented services. First, the payment reference is not for the product (which often has to be paid upfront, thus posing quite a barrier for the user), but a payment per unit time or unit use. Second, such a PSS offers a better means of ensuring client loyalty than the mere purchasing of

products.¹³ The third aspect is related to the fact that PSSs might contribute to better and faster innovation. This is in part related to maintaining low barriers to accessing the service, which also implies access to, and insight into, the needs of clients.¹⁴ However, other aspects play a role. As indicated by Roome and Clarke (2002) amongst others, openness, predisposition to mutual learning and access to networks of other players to discuss strategy are key features of innovative firms. Since PSSs are so user oriented, and in general put on the market through intense co-operations within networks of firms, it could be argued that this helps firms (or the network as a whole) to be innovative.

Analysis of key economic elements per type of PSS

Table 1 scores the eight generic types of PSS against the four key economic criteria as described above in the four elements and their aspects. Of course, for individual PSSs a tailored and quantitative evaluation is necessary to find out whether it is profitable business.

Table 1 shows the following.

- *Product-related services* (1) and *advice and consultancy* (2) usually provide some tangible value for the user by a more efficient use of materials and human resources. This is reflected in some additional material and human resource costs for the provider. A product-oriented company embarking on these types of PSS usually has to make some

¹² Christensen *et al.* (2001) give the dramatic example of IBM. In the early 1980s, this firm covered some 70% of the whole value chain of (main frame) computers and attracted 90% of its added value. Squeezing out less powerful players in the chain seemed a profitable strategy, and IBM started to outsource part of their non-essential activities to enhance return on investment even more. However, one decade later they discovered their mistake. The key strategic bottlenecks in PC production and use were now the operating system (monopolized by Microsoft), and the processor (monopolized by Intel, and, at a distance, AMD). Anyone could build a PC around these essential elements, with no effective way of being really distinctive in design. As a consequence, the power in the value chain shifted dramatically, the processor suppliers and Microsoft capturing most profits, and for a while IBM was in some trouble. See also Raffii and Kampas (2002) on this topic.

¹³ This can take a negative form, e.g. if by signing a contract the client can no longer shop around with other suppliers of consumables and service; but also a positive form: supplying a PSS helps to build a unique client-provider relationship and helps to give the provider unique insight into specific client needs, enabling tailoring of its services more and more over time to this specific client, which in turn creates a situation where competitors are not able to come up with a competing offer unless they make a considerable investment in building a similar relationship.

¹⁴ Think of the well known story that, since copier producers work with a business model based on pay per print, their maintenance staff regularly visits clients and can report back how the copier is used, which can be directly translated into the design or adaptation of copiers.



Table 1. A discussion of the value characteristics of different types of PSS

PSS type	Market value for the user		Costs for provider		Capital needs		Ability to sustain value in future		
	Tangible value	Intangible value	Tangible costs	Risk premium	Inherent capital	Transition costs	% Value captured	Client loyalty	High speed of innovation
1. Product-related service	0/+	0/+	-/0	0	-/0	-/0	0	+	0/+
2. Advice and consultancy	0/+	0/+	0	0	0	-/0	0	+	0/+
3. Product lease	0/+	?	-/0	-/0	-	-	+	-/+	0
4. Product renting or sharing	-/+	--	+	0	-/+	-	?	?	?
5. Product pooling	-/+	--	+	0	-/+	-	?	?	?
6. Activity management	+?	+?	0	-/0	0	-	?	+	+
7. Pay per unit use	+	?	0	?	0	-	+	+	+
8. Functional result	0	?	++/?	--	++/?	--	?	?	+

Key

- ++: Much better than reference (product)
- +: Better than reference
- 0: Indifferent
- : Worse than reference
- : Much worse than reference
- ?: No judgement possible
- Grey: Most problematic areas

investments in capital and organizational transitions. There might be a benefit in terms of lower client barriers (if financial services are included), a higher client loyalty and, due to better client contacts, some increase in the speed of innovation.

- *Product lease* (3) has some tangible value for the user, since various costs and activities are shifted to the provider. The provider might have to make provisions for more careless client behaviour. Since the provider remains as owner of the product, the need for capital is high. Barriers to attracting new clients are low due to low initial investment by the client. User loyalty might improve (as the product plus maintenance, etc. is provided), but the user can still easily switch to

other providers. Since leasing companies use products provided by others, no influence on innovation is assumed.

- *Product renting and sharing* (4) in general demands a tangible sacrifice by the user. He/she now has to put time and effort into getting access to the material artefact. Compensation can come from the fact that he/she no longer needs to bear the capital costs of the product. It is likely that this PSS type scores low in terms of intangible value. Rental equipment in many cases does not contribute to (self-)esteem, or 'priceless' experiences, though there are exceptions ('rent this BMW and be a king for a day'). The organizational system at the provider uses more input of human resources. Since



the provider keeps on owning the product, capital need is high. However, due to the shared use, overall capital need in the system is considerably lower. Due to low initial costs the access barrier for new clients is low.

- *Product pooling* (5). The analysis is virtually the same as for renting and sharing.
- *Activity management* (6). Activity management shifts personnel and material costs from the user to the provider, who has to make gains by organizing the outsourced tasks more efficiently by specialized knowledge. It is important that good performance criteria can be defined, since otherwise discussion about the delivered result can arise between user and provider (risk premium issue). Since activity management is usually arranged via longer term contracts, reasonable client loyalty is ensured. The specialization might lead to a high speed of innovation.
- *Pay per unit use* (7). There is a clear tangible value for the user since various activities (maintenance, etc.) are outsourced to the provider. The providers' position in the value chain becomes better, in relation to direct access to clients and (enforced) client loyalty. The provider has to be able to predict the behaviour of the user, since otherwise no clear cost calculation can be made and a risk premium has to be included. Since the product stays in ownership of the provider additional capital is needed. There are low barriers for new clients, and good client contacts in principle lead to better innovation potential.
- *Functional result* (8). Since the same function is offered, in principle the user could give it the same tangible value. Intangible value is another matter though, and cannot be judged without defining the specific system. In principle, the provider could try to provide a solution with much lower input of human resources and materials. However, since the provider promises a result on a high level of abstraction, agreement on per-

formance indicators, and the level of control in achieving this performance, can be an important (if not prohibitive) problem (which translates to a low score on the risk premium issue). Capital costs could be low, but transition costs high. This model leaves the highest degree of freedom with regard to innovation.

The overall picture is that product-oriented services are the least radical ones and probably easily applicable by traditional product-oriented firms. Use-oriented services are now also common business models, whereas product renting, pooling and sharing seems to have a relatively high chance of creating tangible and intangible client sacrifices. Within result-oriented services, activity management and pay per use are becoming more common. The key problem with these PSSs is the difficulty of agreeing with the user a set of good performance criteria, and the prediction of, or influence on, the behaviour of the user within reasonable margins. This risk element is particularly relevant for the functional result type of PSS, since the provider takes over all the liabilities that in a product-based system were with the user.

The sustainability case: factors influencing sustainability potential

In this article the sustainability of PSS types has been analysed with the help of 'sustainable design rules' (see Manzini, 2002; Zaring *et al.*, 2001; McDonough and Braungart 2001¹⁵). The following reasons for differences in environmental performance of products and PSS have thus been identified (including a tentative indication of the magnitude of environmental impact reductions).

¹⁵ Typically, PSSs can result in lower impacts than products by their inherent design, or by stimulating user and provider behaviour geared towards low material and energy use. Quantitative or semi-quantitative approaches such as LCAs can only be applied to concrete PSS cases and are less suitable in this analysis. Please note that in this article the issue of sustainability focuses on environmental sustainability only.



Mechanisms leading to incremental/average impact reductions (10–20%)

- Incremental efficiency improvements (e.g. by better maintenance due to a maintenance contract in a product-related service). This can lead to a more intensive use or a prolonged life of capital goods, or less use of energy and consumables in the use phase – though in a less radical manner as indicated in the second, third and fourth reasons described below.

Mechanisms leading to average to high impact reductions (up to 50% or factor 2)

- Designing products taking true life-cycle costs into account by the provider, who takes responsibility for these life cycle costs (e.g. in the case of pay per service unit). This is a strong incentive for optimizing the use of energy and consumables, and recycling of product parts and materials where feasible.
- Considerably more intensive use or prolonged life of capital goods used in the system (e.g. in a product renting or sharing situation) than in a traditional product system. Intensive capital good use can also stimulate a quicker replacement by newer, more efficient models.
- Considerably less use of energy and other auxiliary materials in the use phase, e.g. in a product pooling situation. The same use phase in energy and auxiliary material use is shared by various users.
- Use of a considerably more efficient technology made possible by a higher economy of scale (e.g. washing machines in a laundry using gas heated water rather than the electricity heated water used at home).

Mechanisms potentially leading to very high impact reductions (up to 90% or factor 10)

- Application of a radically different technological system with radically lower impacts (e.g. a functional result).

In the next sections, the effects of each type of PSS are discussed, and summarized in Table 2.

Product-related service (1)

The majority of product-oriented PSSs do not imply any change in the technological system or how the user operates it (relating to the third, fourth, fifth and sixth mechanisms identified above). There is no strong incentive in terms of internalizing true life cycle costs in the design process by the provider. There might be some incremental efficiency improvements due to better maintenance, or take-back provisions, although even these might be absent. The user may organize good levels of maintenance by hiring third parties, and take-back schemes might already be legally demanded. Financing schemes have no effect whatsoever. The overall picture is that product-related services can lead to impact reductions, but they are likely to be incremental at best.

Advice and consultancy (2)

The effects here are similar to those for product-related services. Again, the main value lies in the fact that the PSS provider might suggest all kinds of optimization for using the product, which in the end can lead to incremental reductions in environmental impacts.

Product lease (3)

In the case of product lease, it is not clear whether there will be impact reductions or not. In principle, the provider now also takes responsibility for maintenance, repair and control, and this could lead to incremental efficiency improvements: the product has a somewhat longer life span and might use energy and consumables more efficiently by better maintenance, repair and control. In principle, the provider may perceive an incentive to prolong the product life and may design the product accordingly. In most cases, however, lease companies buy the products they lease



Table 2. Relevance of impact reduction mechanisms per PSS type

Mechanism	Relevance per PSS type							
	1. Product related	2. Advice and consultancy	3. Product lease	4. Product renting/sharing	5. Product pooling	6. Activity management	7. Pay per use	8. Functional result
<i>With incremental impact reduction</i>								
Incremental efficiency improvements	+	+	?	?	?	+	+	+
<i>With average to high impact reduction</i>								
Design based on true life cycle costs	?	n.r.	?	?	?	+/?	+	+
More intensive use/prolonged life capital goods	n.r.	n.r.	n.r.	+	+	+/?	+	+
Much less use of energy etc. in use phase	n.r.	n.r.	n.r.	+	+	+/?	?	+
Much more efficient technology by economy of scale	n.r.	n.r.	n.r.	n.r.	n.r.	?	n.r.	?
<i>With very high impact reductions</i>								
Application of a radically different, low impact technology	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	+

Remark: product renting/sharing and pooling have a bonus in that they discourage use of products.

for third parties, and are not responsible for product design. So the incentive felt by the leasing company is not passed on to a designer team directly. Furthermore, the lease in general does not cover many costs in the use phase (e.g. fuel consumption in cars), so neither the lessee nor the product provider will perceive much incentive to do something about energy and consumable use in the use phase. The fact that the user no longer owns the product could even lead to negative effects, such as a careless use shortening its useful life span.

Product renting and sharing (4)

Product renting and sharing implies that same product is now more intensively used. This can have high impact reductions, particularly if the life-cycle impacts are mainly related to the manufacture of the product (compare Wimmer and Züst, 2001). This PSS can have an additional bonus. In general, the user will now have to pay the integrated costs for each time

he/she uses the product, unlike the case for the former PSS types. Also, access to the product is a little more complicated. This implies that in this system the *use of the product in general will be somewhat discouraged*. This might have additional positive environmental effects, if it leads to a less-use situation, or to more frequent use of more environmental friendly alternatives (e.g. public transport as a complement to car renting or sharing).

Product pooling (5)

The analysis for product pooling is similar to that for renting and sharing, with one major difference. Product pooling implies that the same product is used at the same time by more users (e.g. car pooling). This can have even more impact reductions than in the case of sharing and renting, particularly if the life-cycle impacts are related to the use of the product.



Table 3. Tentative (environmental) sustainability characteristics of different PSS types

PSS type	Impacts compared to reference situation (product)				
	Worse	Equal	Incremental reduction (<20%)	Considerable reduction (<50%)	Radical reduction (<90%)
1. Product-related service		←-----→			
2. Advice and consultancy		←-----→			
3. Product lease	←-----→				
4. Product renting and sharing		←-----→			
5. Product pooling		←-----→			
6. Activity management		←-----→			
7. Pay per unit use		←-----→			
8. Functional result		←-----→			

Notes:

- Renting, sharing: radically better if impact related to product production.
- Pooling: additional reductions compared with sharing/renting if impacts related to the use phase.
- Renting, sharing, pooling: even higher if the system leads to no-use behaviour.

Activity management/outsourcing (6)

Activity management or outsourcing usually does not imply a radical change in applied technology, organization etc. However, companies providing this PSS (financially) have to be more efficient than the company who outsourced the activity to stay in business. This can be realized by a more efficient use of capital goods and materials, although it seems unlikely that the gains are more than a few dozen per cent. On top of this, in many cases the efficiency gains are realized on personnel costs rather than material costs, which is less relevant for impact reduction.

Pay per unit use (7)

Two aspects concerning the pay per unit of use PSS are of relevance. First, the provider is responsible for all life cycle costs, which provides a powerful incentive to design a product that in terms of costs is optimized over the life cycle, of which elements can be re-used after the products' useful life. Second, in specific cases (e.g. pay per wash) the user will make a more conscious use of the service, though in other cases (e.g. copiers at work) this issue

plays no role. A very important issue is that the provider feels an incentive to continually improve the product with life-cycle performance in mind.

Functional result (8)

Offering a functional result in principle has the highest potential for impact reduction. At a high level of abstraction, a result is promised and the provider can decide the necessary approach to deliver the result. This provider will therefore try to do so in the most cost-effective way, which bears the promise of a search for radical innovations.

Table 3 below tentatively translates the findings of Table 2 to give an impression of the environmental sustainability potential of the different types of PSS.

The conclusions from this translation are the following.

- Product-related service, advice and consultancy, and product lease types of PSS have probably marginal environmental benefits, since at best mainly incremental change such as better maintenance etc. can be expected. Product lease PSS can even



produce negative environmental effects if the lessee has incentives to use the product in a less careful way than when he/she owns it.

- Product renting, sharing or pooling PSSs can have major environmental benefits if the burden is related to the production of the artefact, since the same product is shared and used more intensively. However, if, in the case of product renting or sharing, the use phase dominates and does not lead to a low use behaviour there is little positive outcome. In such cases, pooling leads to lower impacts since more people make use of the product at the same time.
- An activity management/outsourcing PSS will lead to lower environmental impacts if (monetary) efficiency gains are particularly related to materials and artefacts, and not to time input of humans.
- The pay per unit use PSS overcomes the split incentive between production costs of a product and costs made in the use phase. It is likely that at least incremental gains will be realized, but since the technological system in principle does not change radically, no radical improvements can be expected.
- Functional result PSSs have, in theory, the highest potential since the provider offers a result closer to a final client need and hence has more degrees of freedom to design a low-impact system.

Overall, it can be cautiously concluded that most PSSs will probably lead to some environmental improvements, or at least no worse environmental performance. The exception is formed by PSSs that make users less responsible for careful use of the product (leasing). Improvements tend to be incremental to average at best, though. Such improvements are mainly related to economic efficiency gains, and might therefore be less relevant for human-resource intensive systems. Radical improvements can only be expected in the case of promising functional results.

CONCLUSIONS

The overall conclusions of this paper are not straightforward. True, in comparison to product systems most PSSs analysed have some potential for environmental gains, and in general there is not too much risk that additional impacts will be created.¹⁶ However, it has also become clear that the PSS in general is not a panacea for reaching radical factor 4 or 10 environmental improvements. Of course, in theoretical terms it is easy enough to define a functional result at a high level of abstraction (e.g. a person that needs transport from A to B), and then to conclude that systems can be designed that can deliver this function a factor of 4–10 times more efficiently than the currently dominant product system, i.e. transport by own car. However, it does not work the other way around. Most PSS types cannot be expected to result in such radical gains. Further, the conclusions reached from an analysis of the business and sustainability cases for PSS show that there are a number of interesting contradictions concerning what would be desirable from a sustainability point of view, and what makes good sense for business. The simple thinking that PSS development will automatically result in an environmental–economic win–win situation also seems to be a myth. Some of the contradictions include the following.

- The least problematic PSSs for companies to introduce (in many cases still product oriented) are product-related services and advice and consultancy. These lead at best to some incremental environmental improvements. The same applies, though maybe to a lesser extent, to activity management. Radical changes cannot be expected since the technological system itself basically does not change, and is merely operated more effectively.

¹⁶ Abstracting from rebound effects that might be created if PSS is more cost-efficient than the product, and the saved income is spent on other activities.



- Some PSSs, such as product lease, can lead to less responsible user behaviour and hence an *increase* of environmental impacts.
- Product renting, sharing and pooling in principle can lead to high environmental gains: capital goods are used more intensively and, in the case of pooling, consumables in the use phase are now beneficial for more persons at the same time. However, this category in particular probably has a considerably lower market value than the competing product, due to both tangible and intangible user sacrifices.¹⁷
- The most promising PSS in environmental terms is the function-oriented PSS. However, this PSS particularly needs attention concerning operationalization. There will be plenty of cases where the 'functional result' cannot be operationalized in sufficiently concrete terms, where liabilities related to the promised result are too high, or where the provider simply has insufficiently control if the result is to be reached. These issues can be prohibitive in putting a function-oriented PSS on the market (or otherwise only by demanding a high risk premium).

These findings, incidentally, also indicate some important issues for a research agenda that aims at promoting sustainable PSSs. It is all too clear that product renting, sharing, pooling and functional PSSs are probably the most promising types from a sustainability point of view. Approaches should be developed that overcome the main barriers to implementation for such PSSs, i.e.

- design of product renting, sharing and pooling systems that have a high *intangible* value for the user, while sacrifices with regard to tangible value are minimized;

¹⁷ For instance, recently it became clear that one of the main sponsored car sharing programmes in the Netherlands only had a few thousand subscribers and has no major growth in view. It is all too clear that for the vast majority of the Dutch population such schemes are not a realistic and attractive alternative to owning or leasing an 'own' car. The subsidy of the car sharing organization is now in discussion.

- development of concrete performance indicators for functional PSSs;
- development of approaches which can reduce the liability risks and enhance control over 'production' uncertainties related to functional PSSs.

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BIOGRAPHY

Arnold Tukker (Project Manager SusProNet), Programme Manager Sustainable Innovation, TNO Institute of Strategy, Technology and Policy, P.O. Box 6030, 2600 JA Delft, The Netherlands.

Tel.: + 31 15 269 5450

Fax: + 31 15 269 54 60

E-mail: Tukker@stb.tno.nl