F. Coley and M. Lemon
Journal of Engineering Design
2009, Volume 20, Issue 6, pp543-554

Exploring the Design and Perceived Benefit of Sustainable Solutions: a review

F.J.S.Coley*, M. Lemon

Centre for Resource Management and Efficiency, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK

Tel: +44 1234 750111

Email: f.j.s.coley@cranfield.ac.uk; m.lemon@cranfield.ac.uk

F. Coley and M. Lemon
Journal of Engineering Design

Abstract

The demand for more innovative solutions to meet progressively complex consumer requirements is increasingly at the forefront of design practise and research. Coinciding with this is the stipulation for more environmentally, socially and economically sustainable services. Although many approaches towards the design of more systemic and sustainable solutions exist the terminology to describe them is manifold. Subsequently confusion surrounding the cross disciplinary process that stakeholders are required to follow is increasingly apparent. This paper presents a critical review of multiple design approaches from the perspective of the stakeholders involved and identifies a set of attributes that are common to them. It is concluded that stakeholders could substantially benefit from a supportive framework of common characteristics to enable the integrative design of more systemic and sustainable solutions.

Key words: Design research, design, sustainability, PSS

1. Introduction

As contemporary society is changing both rapidly and profoundly so is the demand for new products and services. Incremental changes to current designs are no longer enough for modern day living and so it seems that radical, innovative step changes are required to fulfil increasing consumer needs. Coinciding with this revelation is the growing concern for the state of the environment, particularly the continued or improved sustainability of our society. Mainstream businesses are launching green initiatives and eco-friendly products in an effort to capitalise on society's apparent shift toward a more environmental ethic. Most green business efforts essentially are attempts to improve upon traditional products by somehow making them more environmentally benign, through, for example, product reformulation or increasing its energy efficiency. However, environmentalists, especially those in the sustainable consumption movement, want businesses to change their products fundamentally in anticipation of shifting consumer values; and thus consumer demand (Morson,

2007). Current technological improvements, although contributing to a potential improvement of the immediate situation, are not adequately addressing the problem as a whole; particularly softer issues such as consumer behaviour and servicing products and economies (Mont, 2006).

The lone ingenious designer, who could do everything by him or herself, is rapidly becoming history (Krippendorff, 2006). Design research suggests that more innovative and sustainable solutions increasingly require the integration of multiple stakeholders with an expansive array of knowledge and expertise. The importance of cross disciplinary collaborations and partnerships within industry is escalating; driven by the need to address complex problems more systemically from a multitude of perspectives (Hebel, 2007; Senge, 1990). Designers, engineers, mechanics, technicians, architects, psychologists, quantitative and qualitative researchers, academics, users and consumers are just some of the stakeholder groups across disciplines that increasingly form these collaborative partnerships.

Subsequently partnerships are accompanied by numerous expectations and requirements and a more extensive network of actors, some of whom were never previously regarded as designers, are becoming heavily involved with the actual process of designing. High levels of multi-disciplinary working not only increases levels of complexity (Mankin *et al.*, 2004) but also creates many more issues and concerns to consider and often they can be conflicting (Howarth and Hadfield, 2006). Kemp (2007) agrees and suggests that traditionally, industrial design, graphic design, user-interface design, advertising, and so on have been separate disciplines, with a product essentially being handed from one to the other in logical sequence. However, delivering the integrated customer experience demanded today requires a more cooperative and, in many ways, more difficult approach.

Over the last decade; multiple approaches to design have focused on the development of products, services and systems for both improved social and environmental sustainability. It appears however that consensus is lacking with regards to the terminology used to describe these approaches and additionally

the process that the consortium of stakeholders are required to follow. Product Service System (Mont, 2006), Solution Oriented Partnership (Manzini *et al.*, 2004), Whole System Design (Hawken *et al.*, 1999), Highly Customised Solution (Manzini *et al.*, 2004), Eco-Efficient Product Service System (Mejcamp, 2000), Sustainable Product Service System (Heiskanen and Jalas, 2003), Integrated Solutions (Van Der Zwan, 2003), Advanced Industrialisation (Manzini *et al.*, 2004), Strategic Design (Manzini and Vezzoli, 2003), Customer Solutions (Cornet et al., 2000 in Van der Zwan, 2003), and Systemic Innovation (Little, 1987) are just some of the terms that have been coined for projects of a systemic and holistic nature.

As Marxt and Hackiln (2005) emphasise; it is widely accepted in academia and industry that new products or services, which are developed on a regular basis, are one of the main factors for the sustainable success of companies. Although the fact in itself is clear, the terminology used to describe this professional and academic field is manifold. In an attempt to individually distinguish these multiple approaches to the design of more systemic and sustainable solutions; Table 1 presents a number of different terms alongside definitions taken from literature.

Although the definitions within Table 1 appear to focus on individual aspects of the solution and / or the design process there is a significant overlap of aims and purpose. Subsequently it has been identified that there are relatively few studies in the relevant literature which provide a model or guide as to how stakeholders are to embark on such a messy and complex design process. Very little is available for the phase that bridges concept and detailed design, a phase that Ruder and Sobek (2007) term system-level design.

Table 1: Definitions of multiple design approaches taken from literature

Term	**Definition**
PRODUCT SERVICE SYSTEM (Manzini and Vezzoli, 2003)	An innovation strategy, shifting the business focus from designing physical products only, to designing a system of products and services which are jointly capable of fulfilling specific client demands
ECO-EFFICIENT PRODUCT SERVICE SYSTEM (Manzini and Vezzoli, 2003)	When a Product Service System assists re-orient current unsustainable trends in production and in consumption practises
ECO-EFFICIENT SERVICE (Brezet *et al.*, 2001)	Eco-efficient services are systems of products and services which are developed to cause a minimum environmental impact with a maximum added value.
WHOLE SYSTEM DESIGN (Rocky Mountain Institute, 2004)	Whole systems design means optimising not just parts but the entire system … it takes ingenuity, intuition, and teamwork. Everything must be considered simultaneously and analysed to reveal mutually advantageous interactions (synergies) as well as undesirable ones
SOLUTION ORIENTED PARTNERSHIP (Manzini, 2003)	A sustainable system of products and services delivered in a highly effective way by a network of local and global partners which is able to address specifically each given user in its given context
INTEGRATED SOLUTION (Wise and Baumgartner,1999 in Van der Zwan, 2003)	Integrated solutions combine products and services into a seamless offering that addresses a pressing customer need
ADVANCED INDUSTRIALISED SOLUTIONS (Manzini, 2003)	Solutions based on collaboration between social players that give rise to highly contextualised services (services that are sensitive and appropriate to the specific characteristics of the contexts in which they are provided), which are also equally effective and efficient (able to offer high quality results while minimising economic and environmental costs)
CUSTOMER SOLUTIONS (Cornet et al., 2000 in Van der Zwan, 2003)	Typically developed as a combination of products, services, and knowledge, a solution is a supplier's customised response to a customer's pressing business need. It is an innovative construct built on a foundation of cooperation and mutual trust that revolutionises the customer value proposition.

The aim of this paper is to further explore approaches to the design of more systemic and sustainable solutions. More specifically, due to the apparent lack of certainty surrounding the design process stakeholders are required to follow, each approach shall be reviewed and compared with reference to the following questions:

- What is the focus of the approach?
- What guidelines are stakeholders given?
- Does the approach result in more sustainable solutions?
- What is the intended outcome of the approach?

In addressing these questions a set of common attributes will be sought and tabulated. It will then be determined whether there is value in developing a generic model of best practise for the design of more systemic and sustainable solutions or, alternatively, whether each approach is unique and subsequently requires stakeholders to adapt to a distinctive design process.

2. Multiple approaches to the design of more systemic and sustainable solutions

2.1 Product service systems

"A Product Service System suggests the need to link hard and soft issues such as technology and sociology, products and services and to view existing environmental problems from a systemic perspective"

(Mont, 2006)

One of the first attempts at formally producing more systemic and sustainable solutions and so far the most widely researched approach has been Product Service Systems (PSS) (Baines *et al.*, 2008). Environmentalist-driven authors have argued that, unless ways can be found to separate economic growth from environmental pressure, mankind would face near certain disaster (Von Weizacker *et al.*, 1997). Therefore, rather than developing a product to fulfil consumer needs, attention turned to realising final customer needs with a focus on sustainability. Authors suggest that not only would this new perspective address the design of need fulfilment systems with Factor 4 – 10 sustainability improvement but, in doing so, would present the designer with more freedom to create innovative solutions (Schmidt-Bleek, 1993).

An example of a proposed PSS with a combined solution of products and services was suggested by the ESRC Centre for Business Relationships, Accountability, Sustainability and Society (BRASS, 2006) which argued that in order for the automotive industry to address social, environmental and economic pressures a radically alternative vision must be adopted. The suggestion of micro factory retailing (MFR) was based around the concept of providing personal mobility delivered by means of environmentally optimised vehicles. The cars or modules could be mixed and matched according to customer requirements, but all would be based on low customer cost, high labour input, environmentally and socially optimised technologies, as sustainable as can be achieved (Williams, 2006). Although the case for MFR has its merits it is unclear how this alternate vision is to be adopted. There is little practical guidance as to how radically innovative concepts such as this are to be introduced into the automotive industry. Furthermore traditional working environments and deeply rooted values and ethics are just some of the issues that may stand in the way of such radical change. Implementing new concepts into old systems appears to be challenging; often new designs do not succeed without re-addressing the system that it is to live within.

A key attribute of PSS for many authors appears to be the shifting of focus from designing physical products only, to designing a system of products and

services which, through innovative strategies, are capable of fulfilling specific client demands (Manzini and Vezzoli, 2003). Much of the research surrounding PSS has focused on the internal benefits that the approach is thought to provide to business. In a report addressing opportunities for sustainable solutions, conducted by the United Nations Environment Programme (UNEP), it was suggested that PSS is a new concept for business to improve their sustainability performance. The report went on to argue that, as a natural step after efforts to clean up production processes and re-design products, the new approach invites business to shift its focus from selling those products to selling the utility (Manzini and Vezzoli, 2002). However, it has been more recently acknowledged that the ongoing transition towards service development or service economy increasingly requires the development of partnerships and networks (Christenson, 2007). The more we move in the direction of offering industrialised solutions instead of single products or services, the more complex the system of actors available to deliver such offers become (Krucken and Meroni, 2006). In fact, to find holistic solutions to the issues of modern society the concept of PSS calls for the development of multidisciplinary approaches that require inputs from a broad range of disciplines, such as, economics, management, environmental studies, sociology, psychology, product design and engineering (Mont, 2006). Subsequently it appears that future research surrounding PSS would benefit from focusing on the practical facilitation of cross disciplinary integration for the development of more sustainable opportunities rather than addressing internal business strategy alone.

Acknowledging that the cohesion of various actors is essential to developing a successful PSS, Morelli (2006) suggests that there are three key stages for a designer to follow:

1) Work on the identification of the actors in the network, on the basis of the defined analytical frameworks;
2) Work on possible PSS scenarios, verifying use cases, sequences of actions and actors' role; defining the requirements for a PSS and the logical and organisational structure of a PSS;

3) Work on representation and management tools to represent a PSS in all its components, i.e. physical elements, logical links and temporal sequences.

Morelli (2003) suggests that, although currently there are no tools in place to aid designers with these steps, other disciplines do in fact utilise methods which could be integrated into the discipline of design, and PSS in particular. There is, however, no current research that suggests this integration has been carried out or even attempted.

Further to the emphasis placed on actor identification Bijker (1987) highlights the relevance of the extended network of actors. He views relevant actors as not only those social groups that actively participate to the development of the PSS, but those actors that indirectly participate in such a process and even those that may oppose it. The integration of stakeholders into the design process is becoming ever more crucial for the development of a systemic solution and due to the complexity of actors involved with the development of a PSS, the designer's role is having to change. The lone ingenious designer, who could do everything by him or herself is rapidly becoming history (Krippendorff, 2006) and designers now need an awareness and understanding of complex and wide ranging issues when applied to a new product, service or system (Howarth and Hadfield, 2006). Designers are increasingly required to have additional skills and expertise in methods, management and organisation. There is a significant gap in the literature, however, regarding what these skills are and how the designer is to obtain them. Furthermore, it needs to be acknowledged that designers cannot have all the knowledge and skills necessary for the design of a more sustainable solution. Future research must stop focusing on the individual role of the designer and turn towards the facilitation of numerous actors within the process of design.

Although much literature focuses on the benefits of PSS the definition of specific methodologies to manage some critical aspects of the design process of PSS has rarely been considered in design-related disciplines (Morelli, 2006).

Given this it is no surprise that a sustainable PSS theory with explanatory and predictive power is still largely absent (Tukker and Tischner, 2006). Additionally the transfer of PSS from academia to practice in UK manufacturing firms is still being attempted (Cook *et al*., 2006). This is necessary not only to move the concept of PSS forwards through an improved evaluation of its practical utility but also to communicate an improved understanding of it to related disciplines.

As previously suggested, a significant aim of a PSS is to develop sustainable solutions (Schmidt-Bleek, 1993) however the success of this aim is questionable and has even been described as a 'myth' (Tukker and Tischner, 2006). The sustainability oriented literature has made relatively few attempts to come to a structured visualization of PSS (Tukkler and Tischner, 2004). Manzinni (2003) suggests that it is generally agreed that PSS does not necessarily lead to sustainable solutions and in fact that, some PSS approaches could even generate unwanted side effects. He does however suggest that when a PSS does address current unsustainable trends in production and consumption practises it is usually referred to as a Sustainable or Eco-Efficient PSS. This further categorisation adds to the complexity and confusion surrounding design approaches and furthermore begs the question: what is the difference in the approach towards a PSS and an Eco-Efficient PSS?

2.2 Eco-Efficient Product Service Systems

"An eco-efficient service is a certain product-service mix, which has a higher added value, and a smaller environmental impact compared to a similar product-service mix or a situation in which the activity was not performed at all"

(Zaring et al., 2001)

Van der Zwan (2003) suggests that terms such as eco-efficient PSS, eco-efficient services, sustainable services and systems and eco-services, although with slightly different meanings, simply stress a particular element of the offering.

From a designer's perspective it is suggested that the main difference between a regular PSS and an eco-efficient service can be found in the multiple perspectives that are adopted. By pushing the boundaries, extending the actor network and adopting even more potential contexts, the larger the potential for sustainable innovation (Van der Zwan, 2003). While agreeing with this comment; it can be argued that the consultation of multiple perspectives does not differ significantly from any other attempt at producing a more sustainable solution. Consequently it is unclear how a solution produced by this approach would be more sustainable than any other. Manzini and Vezzoli (2003) suggest that the more the notion of whole system optimisation is broadened (beyond a single product life cycle to an interconnected series of product and service life cycles), the greater is the potential for eco-efficiency gains. Additionally the organisation of stake holder involvement is more complex and could increase the likelihood of failure. However again, as shown in the following example, through the integration of multiple stakeholders the potential for eco-efficiency gains are potentially greater.

The Allegrini service proposed a new way of supplying detergents for house keeping as an eco-efficient PSS based on the home delivery distribution of detergents (Manzini and Vezzoli, 2003). As both a product (the detergent) and a service (home delivery) the concept focuses on providing:

- added value for the producer by minimising overall packaging costs and postponing the cost of new product manufacture;
- added value for the consumers through an increase in comfort, since the products arrive directly to home and waste disposal efforts are reduced;
- environmental benefits obtained by the optimisation of the distributed process, in terms of both packaging and transportation.

The study does not, however, provide details of how the suggested environmental benefits were measured. Unless significant numbers of consumers were to adopt this service, such benefits may well be negligible.

Furthermore it is argued that an environmentally friendly solution is ineffective without successful implementation into the surrounding system; the design of practical implementation of a concept should be as important as the design of the concept itself.

As literature is limited regarding the practical development of an eco-efficient PSS it is difficult to identify how the design process would differ from that of a regular PSS. In a study by Van der Zwan (2003) an attempt to identify several commonalities within the process of designing more systemic and sustainable solutions resulted in the following points:

- The customer need is the starting point of the offer;
- The provider is involved throughout the lifecycle;
- They guarantee a certain level of performance;
- They focus on creating added value.

This top level representation highlights what little work has been carried out within this area. Furthermore it is still suggested that the environmental implications of introducing eco-efficient services are poorly studied (Van der Zwan, 2003) and that there is so far no conclusive evidence that the use of these services contributes positively to sustainable development (Mont, 1999).

In a review of eco-efficient producer services (EEPS); Bartolomeo *et al.* (2003) investigated three different typologies of eco-efficient services:

- Product-based services
- Electronic substitution services
- Information based services

The extensive study concluded that there could be no general assumption that services were inherently environmentally superior to products. Furthermore; in cases where improved sustainability was reached, only a minority appeared to have been driven by environmental factors. For most, environmental

considerations were only stumbled upon 'by accident' (Bartolomeo *et al.*, 2003). It is suggested that the current shift towards services in industry is unlikely to lead to radical eco-efficiency improvements by its own momentum (Heiskanen and Jalas, 2003). Instead researchers and practitioners are advised to look towards how existing services could be made more sustainable as opposed to developing new ones (Heiskanen and Jalas, 2003).

It has so far been difficult to differentiate between the highlighted approaches, particularly from the perspective of the process that stakeholders are required to follow. One recurring attribute, however, appears to be the intensity of collaboration and integration that is required. The following section investigates this specific collaboration through solution oriented partnerships, another approach to the design of more sustainable solutions.

2.3 Solution Oriented Partnerships

"A sustainable system of products and services delivered in a highly effective way by a network of local and global partners which is able to address specifically each given user in its given context"

(Manzini et al., 2004)

Morelli (2006) has defined a Solution Oriented Partnership (SOP) as the partnership that is generated by the convergence of different stakeholders for the generation of the solution within a PSS. He elaborates by suggesting that the glue for such a partnership is attractive design solutions based on a mix of material and immaterial components which satisfy the requirements of each of the stakeholders. The SOP approach is included within this review due to its aim of producing a more sustainable solution through the use of collaboration and partnerships which appears comparable to that of a PSS.

An example of a SOP is La Fiambrera (Lambert *et al.*, 2004) which has been documented as part of the highly customised solution (Hics) project. La

Fiambrera was a venture which succeeded in providing lunches to two completely different groups of people that shared provision needs. The system creatively and successfully combined economic business interests and the achievement of social benefits to provide a highly customised solution to fulfil local needs (Lambert *et al.*, 2004). This project is unique as not only does it present evidence of the benefits of the approach but also provides details of the complex integration of multiple stakeholders that was undertaken in order to reach a more sustainable solution.

Introducing yet another term to the sustainable solution mix, Manzini *et al.*,(2004) suggest that SOP's aim; to put forward ideas and useful instruments for the development of solutions, can be described as 'advanced industrialised solutions'. He explains that these solutions are based on collaboration between social players and give rise to highly contextualised services (services that are sensitive and appropriate to the contexts in which they are provided) which are equally effective and efficient (able to offer high quality results while minimising economic and environmental costs).

As the name suggests a SOP rigorously emphasises development of a collaborative partnership; the process of building a network of partners, capable of effectively working together to design and deliver a solution is fundamental (Burns and Evans, 2004). The integration of multiple stakeholders is again a fundamental attribute to this type of solution.

Jegou and Joore (2004) propose that there are four main objectives that a SOP approach should aim to achieve:

1) Combining stakeholders that would normally not work together like profit and non-profit organisations, multinationals and SME's, global and local players;
2) Industrialised solutions based on a global platform of products, services and knowledge combined with specific local solution elements;
3) Contextualised solutions that are focused on a specific user in a specific context, and can be adapted to fit other related contexts of use;

4) Sustainable solutions that are both profitable for companies and beneficial for society.

These objectives highlight the few subtle differences between a SOP and the approaches that have been reviewed. The focus on customisation and the emphasis placed upon local business are new attributes and would require additional skills and abilities of the stakeholders involved.

SOP is a relatively recent classification and has only been applied to a limited number of projects. It is, however, one of the few approaches to specifically document the role of the designer and provide a small amount of guidance as to how stakeholders should approach the process of providing a more systemic and sustainable solution.

Due to the lack of examples it is also difficult to assess the success of the solution from an environmental perspective. The inclusion of local produce and business is a positive step however the emphasis put on customisation raises questions of cost and effort to fulfil the needs of individual customers.

2.4 Whole System Design

"Whole-systems thinkers see wholes instead of parts, interrelationships and patterns, rather than individual things and static snapshots. They seek solutions that simultaneously address multiple problems"

Anarow et al., 2003

For generations, engineers, scientists and managers prepared themselves to solve complex problems by becoming increasingly specialised and reducing problems to their constituent parts and focusing their attention on each part. As a result, architects design a building, mechanical designers devise its heating system, lighting designers draw up plans for illumination and interior designers plan its internal spaces. This separation of design functions and processes often

results in inefficient design, construction delays, oversized heating systems, higher costs and unnecessary environmental impacts (Anarow *et al.*, 2003).

A whole system design (WSD) approach encourages those involved to regard a problem as a whole system and not just to concentrate on one particular component of that system. Additionally, it recognises that a problem is created by every part of the system in which the problem is embedded, and that the problem can and should be addressed at every level. When developing a solution the same forces exist and it should be recognised that interventions within a specific location will impact throughout the system; this requires understanding and management. Anarow *et al.,* (2003) recognise that the approach focuses on interactions between the elements of a system as a way to understand and change the system itself. Whole-systems thinking pays close attention to incentives and feedback loops within a system as ways to change how a system behaves (Senge, 1990). Without this whole system perspective crucial impacts between components could be missed, therefore disrupting the system as a whole.

Hawken *et al.*, (1999) are perhaps the first authors to begin to outline a whole system approach from the perspective of the designer. They describe the approach as being a change or shift in design mentality through which designers are required to stop using ‘rules of thumb’ and to start asking different questions. The whole system design approach emphasises the intelligent application of existing technologies and the use of cross fertilisation to discover innovative ways of applying these technologies to alternative components of a problem. Each time practical limits to innovation seem to be approaching, or even limits imposed by the laws of physics, Hawken *et al.,* (1999) suggest that ways can be devised to evade those limits by redefining the problem. Ways of evading these limits, however, are not suggested and furthermore an approach to the redefining of problems is not proposed. Although it is acknowledged that each design context provides a unique set of problems it is thought that research into WSD would benefit from the identification of methods through which to approach these problems.

Authors suggest that understanding the dynamics of a system is integral to the whole system approach (The Rocky Mountain Institute, 2004; Gunderson and Holling, 2002). The Rocky Mountain Institute highlights systems thinking as the method that should be utilised not only to point the way to solutions to particular resource problems, but also to reveal interconnections between problems, which often permits one solution to be leveraged to create many more. An example of where the whole system design approach was used successfully is within Walmart stores. Through the use of a Charrette (Lennertz and Lutzenhiser, 2006) Walmart stores adopted a Whole Building Design approach and subsequently implemented natural day lighting within several of their experimental stores through the use of multiple sky lights. Not only did the implementation result in light saving 300,000 kwh a year but reduced the energy required to cool the building as lights give off heat; provided an increase in sales due to happier customers and reduced staff turnover due to happier staff. While the charrette was first developed for use by architects and specifically related to building design it is easy to visualise how it could be integrated to many other WSD solutions and contexts. Additionally, in the context of this paper, this provides the whole system approach to design with a unique tool through which designers can learn to develop the skills necessary to develop more holistic solutions.

The concept of WSD is difficult for those involved including designers but is suggested that a combination of ingenuity, intuition, teamwork and simultaneous consideration of all components will result in the teasing apart of the problem to reveal mutually helpful interactions allowing the whole system to be optimized and not just individual parts (RMI, 2004). The identification of further tools and techniques would provide substantial guidance and support to actors embarking on the design of more sustainable solutions in the future.

Although, like other approaches to designing more systemic and sustainable solutions, it has been suggested that WSD could encourage sustainable solutions the approach does not automatically yield sustainable production and consumption systems. Anarow *et al.* (2003) state however, that

sustainability cannot be achieved in the absence of whole systems thinking, a skill that appears to be essential to a designer of more sustainable solutions.

3. Discussion and Conclusions

Industry is under increasing pressure to produce innovative solutions which fulfil the rapidly growing needs of contemporary society. This pressure is ever-increased by the requirement to adopt a more sustainable approach to the design and manufacture of products and services. This paper has demonstrated the confusion surrounding the multiple approaches to the design of more sustainable solutions due to the numerous definitions and interpretations currently being used within relevant literature. Key approaches have been discussed including PSS, eco-efficient PSS, SOP and WSD, with the aim of reviewing each against the questions highlighted in section 1. Table 2 provides a direct comparison of the reviewed approaches against the pre-selected questions.

From the table it is clear that there are a lot of similarities between the design approaches. Possibly the most obvious characteristic is that ultimately each approach aims to produce a more sustainable solution in the form of a product and / or service. It remains unclear, however, as to how successful each approach is at producing significantly more environmentally sustainable results. This lack of clarity is due to a limitation in the number of examples that exist and a gap in research and or the literature regarding the analysis of examples that do exist. Future research would benefit from quantifiable studies exploring and comparing the sustainable quality of the results from these design approaches. It has been suggested, however, that there does not seem to be any way to measure the environmental benefits of services in general and, even in specific cases, calculations are complex and surrounded by many uncertainties (Heiskanen and Jalas, 2003). The positive attention and awareness being created by such projects, however, is definitely a step forward for industry.

Further utilisation of systemic approaches to design should place even greater emphasis on environmental concerns and again designers would benefit from tools, techniques and methods to aid them with this challenge.

Table 2: A comparison of design approaches

	PSS	**Eco-efficient PSS**	**SOP**	**WSD**
What is the focus of the approach?	Added value, fulfilment of customer requirements,	Added Customer and Producer Value, sustainable solutions for wider contexts	Highly customised solutions, highly focused on both the solution and the design	Identification of relationships between components of a system
What guidelines are stakeholders given?	Change in focus, inclusion of multiple perspectives	Pushing the boundaries, extending the actor network	Stakeholder involvement, Emphasis on Collaboration, Network of Partners	Change / shift in design mentality, Systemic thinking, The use of Charrettes
Does the approach result in more sustainable solutions?	Unclear	Unclear	Unclear, positive use of local produce and business	Unclear, positive use of systemic thinking
What is the intended outcome of the approach?	Products and / or services	Products and / or services	Products and / or services, partnership between local business and globalisation	Products and / or services

The reviewed approaches appear to be divided in their emphasis between a solution oriented approach and a process oriented approach. Through use of the term ‘service’ PSS immediately appear to confine the desired outcome to the design of ‘a system of products and services’ (Manzini and Vezzoli, 2003). In

comparison, SOP and WSD primarily offer a process oriented approach. The terms ‘partnership’ and ‘whole system’ provide an indication as to the type of approach that is required of the design team and puts no boundary around the intended solution.

It is clear that authors still recognise the role of the designer as crucial to the design, development and production of more systemic and sustainable solutions. It is also clear, however, that the integration of stakeholders from multiple disciplines is necessary to enable a more holistic and subsequently sustainable solution to be reached. Few studies have been carried out into the integrative process both designers and additional stakeholders within this type of design process should take. It is currently unclear what skills, abilities and experiences actors are required to draw upon and furthermore, tools, techniques and methods to aid the process are extremely limited.

From the review of literature presented within this paper it has been possible to identify several attributes that are common to the design approaches explored. These are presented in Table 3. The table suggests that an extended framework of these attributes would be a useful tool for a designer, guiding the development of required trans-disciplinary skills to be practised across various contexts. It is thought that by grouping and emphasising different aspects a model of generic attributes would have the potential to be defined by and help to define multiple design problems. Furthermore it is argued that the development of such a tool should help to address the confusion surrounding the vast array of terminology currently utilised to define design approaches.

Table 3: Generic attributes across design approaches

Attribute	**Description**
Focus	Designers are required to adopt a change in design mentality, start asking different questions and to stop relying on 'rules of thumb'
Design Thinking	Systemic thinking, seeing the system as a whole, identifying relationships between the components of a system
Multiple Perspectives	Inclusion of stakeholders within the design process, identification of actual consumer requirements, inclusion of the provider throughout the lifecycle
Expansive Network	The development of a network of partners to provide multiple resources and knowledge
Collaboration	Partnerships across disciplines and companies
Context Expansion	The design of solutions that can be implemented across multiple contexts
Customisation and Globalisation	The design of industrialised solutions based on a global platform which can be individually customised
System Level Innovation	Designers are encouraged to develop solutions at system level rather than introducing incremental changes

The main downfall to systemic design approaches is that, although academics would like the approaches to be taken up by industry, they struggle to find the much needed demonstration projects and pilots to generate sufficient knowledge and experience (Van der Zwan, 2003). Future projects utilising these approaches should provide the design research community with answers regarding the design process, required skills and also more of an insight into sustainable success.

References

Anarow, B. Greener C. Gupta V. Kinsley M. Henderson J. Page C. and Parrot K. 2003. Whole-Systems framework for sustainable consumption and production. 807,1-51. Report for Danish Ministry of the Environment, Denmark

Baines, T., *et.al.* 2008 State of the art in Product-Service Systems, *IMechE journal of Engineering Manufacture*. (In Press).

Bartolomeo, M. Maso D. Jong P. Eder P. Groenewegen P. Hopkinson P. James P. Nijhuis L. Orninge M. Scholl G. Slob A. and Zaring O., 2003. Eco-Efficient producer services - What are they, how do they benefit customers and the environment and how likely are they to develop and be extensively utilised? *Journal of Cleaner Production,* 11, 829-837.

Bijker, W. E. Hughes T. P. and Pinch T. J., 1987. *The social construction of technological systems: New directions in the sociology and history of technology.* Cambridge, MA, MIT Press.

Brass. *Micro factory retailing* [online]. Available from: http://www.brass.cf.ac.uk/ [Accessed 10/10/07]

Brezet J.C., Bijma A.S., Ehrenfeld, J., and Silvester, S., 2001 *The design of eco-efficient services.* VROM. Delft University of Technology (NL)

Burns, A., Evans, S., 2004. Tools for co-ordinating solution oriented partnerships. Milton Keynes, UK, Oscar Press.

Christenson, C. (2007) What is so sustainable about services, *Design Philosophy Papers*, 03-4.

Cook, M. Bhamra T. and Lemon M., 2006. The transfer and application of

product service systems: from academia to UK manufacturing firms. *Journal of Cleaner Production*, 14 (17), 1455 - 1465.

Cornet, E. Katz R. Molloy R. Schadler J. Sharma D. and Tipping A., 2000 *Customer solutions: from pilots to profits.* Viewpoint, Booze Allen and Hamilton.

Gunderson, L. H. and Holling, C. S., 2002. *Panarchy: Understanding Transformations In Human And Natural Systems.* Island Press

Hawken, P. Lovins A. and Lovins H., 1999 *Natural capitalism creating the next industrial revolution.* USA, Little Brown.

Hebel, M. Light bulbs and Change: systems thinking and organisational learning for new ventures, *The Learning Organization*, **14**:6, 499-509

Heiskanen, E. and Jalas, M., 2003 Can services lead to radical eco-efficiency improvements? A review of the debate and evidence. *Corporate social responsibility and environmental management* 10, 186 – 198.

Howarth, G., and Hadfield, M., 2006 A sustainable product design model. *Materials and Design, 27, 1128 - 1133*

Jegou, F. and Joore P., 2004. *Food delivery solutions: cases of solution oriented partnership.* Milton Keynes, UK, Oscar Press.

Kemp, D., 2007 *The new game in design: collaboration and the creation of the Xbox 360* [online] Available from: http://www.core77.com/reactor/04.06_xbox.asp [Accessed 10/10/07]

Krippendorff, 2006. *The Semantic Turn: A new foundation for design.* USA, Taylor and Francis Group.

Krucken, L. and Meroni A., 2006 Building stakeholder networks to develop and deliver product-service-systems: Practical experiences on elaborating

pro-active materials for communication. *Journal of cleaner production*, 14 (17), 1-7.

Lambert, J. Vidal L. and Marien M. La Fiambrera. *In:* F. Jegou, P. Joore, eds. *Food delivery solutions*. 2004. Milton Keynes, UK, Oscar Press.

Lennertz, B., and Lutzenhiser, A., 2006 *The Charrette Handbook: The Essential Guide for Accelerated, Collaborative Community Planning.* Amer Planning Assn

Little, S., 1987 Incremental and systemic innovation strategies: Reflections of technical choice'. *Design studies* 8, 41 – 54.

Mankin, D., Cohen, S., and Fitzgerald, S. P., 2004 Developing Complex Collaborations: Basic Principles to Guide Design and Implementation. *Complex Collaboration: Building the Capabilities for Working Across Boundaries,* 10, 1 - 26

Manzini, E. Solution oriented partnership: introduction. *In:* F. Jegou and P. Joore, eds. *Food delivery solutions*. 2003. Milton Keynes, UK, Oscar Press.

Manzini, E. Collina L. and Evans S., 2004. *Solution oriented partnership how to design industrialised sustainable solutions.* Milton Keynes, UK, Oscar Press.

Manzini, E. and Vezzoli, C., 2002. Product Service Systems and Sustainability: Opportunities for sustainable solutions. United Nations Environment Programme, Milan, Italy.

Manzini, E. and Vezzoli C., 2003. A strategic design approach to develop sustainable product service systems: examples taken from the environmentally friendly innovation Italian prize. *Journal of cleaner production* 11, 851-857.

Marxt, C., and Hacklin, F., 2005. Design, product development, innovation: all the same in the end? A short discussion on terminology. *Journal of Engineering Design,* 16 (4), 413 – 421

Mejcamp, R., 2000 *Changing consumer behaviour through eco-efficient services.* PhD Thesis. Delft University of Technology.

Mont, O., 2006 Editorial. *Journal of cleaner production*, 1-4. 2006.

Mont, O., 1999 *Product-service systems, shifting corporate focus from selling products to selling product-services: A new approach to sustainable development.* AFR Report 288. Sweden.

Morelli, N., 2006 Developing new product service systems (PSS): methodologies and operational tools. *Journal of cleaner production*, 14 (17), 1495-1501.

Morelli, N., 2003 Product-service systems, a perspective shift for designers: a case study: the design of a telecentre. *Design studies* 24, 73-99.

Morson, K., 2007 *The push to define green* [online] Available from: http://www.stratfor.com/products/premium/read_article.php?id=293793&selected=Stratfor+Weekly [Accessed 10/10/07]

Rmi., 2004. *Home energy brief # 9, whole system design* [online]. Available from: http://www.rmi.org/sitepages/pid390.php [Accessed 10/10/07]

Ruder, J. A. and Sobek, D. K., 2007. Experiment on a system level design tool. *Journal of Engineering Design, 18, 327 - 342*

Schmidt-Bleek, F., 1993 *Wieviel umwelt braucht der mensch?: MIPS - das mab fur okologisches wirtschaften*. Berlin, Germany, Birkhauser.

Senge, P.,1990. *The Fifth Discipline*, Doubleday, New York.

Tukker, A., Tischner, U., 2004 'New Business for Old Europe' *Report for Suspronet*

Tukker, A. and Tischner U., 2006 Product Services As a Research Field: Past, Present and Future. Reflections From a Decade of Research. *Journal of Cleaner Production*, 14 (17), *1552-1556*

Van Der Zwan, F., 2003. *Integrated solutions as a new perspective for eco-efficient services: a cross industry exploration.* PhD Thesis. Cranfield University.

Von Weizsacker, E. Lovins A. and Lovins H., 1997 *Factor 4: Doubling Wealth Halving Resource Use*. Earthscan.

Williams, A., 2006 Product-service systems in the automotive industry: the case of micro-factory retailing. *Journal of cleaner production* 14 (17), 172-184.

Wise, R. and Baumgartner P., 1999 Go downstream: the new profit imperative in manufacturing. *Harvard Business Review*, October, 133-141.

Zaring, O. Bartolomeo M. Eder P. Hopkinson P. Groenewegen P. James P. de Jong P. Nijhuis L. Scholl G. Slob A. and Orninge M., 2001 Creating eco-efficient producer services. Sweden, *Gothenburg Research Institute*.