Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Cleaner Production 11 (2003) 883–895
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

Developing sustainable products and services

D. Maxwell [a,b,*], R. van der Vorst [b 1]

[a] *Environment Unit, Enterprise Ireland, Glasnevin, D9 Dublin, Ireland*
[b] *Environmental Policy and Management Group (EPMG), Department of Environmental Science and Technology, Faculty of Sciences, Imperial College of Science, Technology and Medicine, RSM Building, Prince Consort Road, London SW7 2BP, UK*

Received 5 September 2002; accepted 27 October 2002

Abstract

In light of increasing pressures to adopt a more sustainable approach to product design and manufacture, the requirement to develop sustainable products is one of the key challenges facing industry in the 21st century. Hence, the concept of developing sustainable products as well as services is evolving as a key element of Cleaner Production. Sustainable product development initiatives (mainly through eco-design) have been evolving for some time to support companies develop more sustainable products. Ireland has been running the highly successful Environmentally Superior Products (ESP) initiative that supports industrial companies to incorporate a more sustainable approach to the development of products and/or services. The lessons learned from the ESP and other global Sustainable Product and Service Developments in industry and research, are being used to develop a method for effective sustainable product and/or service development (SPSD) in industry. The method is designed to provide pragmatic guidance to business and industry for developing sustainable products and services as well as incorporating this approach within existing corporate strategy, cleaner production and product development systems. This method is being developed by the authors at the *Environmental Policy and Management Group (EPMG), Department of Environmental Science and Technology, Imperial College London, UK* in conjunction with industry and practitioners. The method provides a framework for implementing SPSD throughout the entire lifecycle of a product and/or service. It can be used to identify, assess and implement the options for optimum sustainability in the design and development of a product and/or service. This paper describes the key features of this method.

Keywords: Sustainable products and services; Sustainability; Eco-design; Environmental management; Life cycle approach; Product service systems

1. Introduction

In response to the shift in environmental policy and law towards products (through initiatives, e.g. Integrated Product Policy and Extended Producer Responsibility for packaging, cars and electronics),[2] there are increasing legal, market and financial pressures on manufacturing industries to develop sustainable products. For some time, concepts, approaches and tools have been evolving to help industry meet this aim. These include eco-design and sustainable product development. The authors at the *Environmental Policy and Management Group (EPMG), Imperial College London, UK,* have been researching industry requirements for developing sustainable products and the ability of existing approaches and tools to meet these requirements. The research has identified a

* Corresponding author. Tel.: +353-1-808-2612; fax: +353-1-808-2259.
E-mail addresses: dorothy.maxwell@enterprise-ireland.com (D. Maxwell); http://www.enterprise-ireland.com/esp (D. Maxwell); r.van.der.vorst@ic.ac.uk (R. van der Vorst); www.env.ic.ac.uk/research/epmg/EPMGFrontpage.html (R. van der Vorst).
[1] Tel.: +44-20-7594-9289; fax: +44-20-7594-9304.

Abbreviations: EMS, environmental management system; ESP, environmentally superior products; LCA, life cycle assessment; MNC, multinational corporation; OEM, original equipment manufacturer; PSS, product service system; SCD, supply chain dynamics; SCM, supply chain management; SME, small and medium sized enterprise; SPSD, sustainable product and service development; TBL, triple bottom line

[2] The end of life vehicles (ELV) Directive [1] is focused on the automotive sector. The draft Waste Electrical and Electronics Equipment (WEEE) and Restriction of Hazardous Substances (ROSH) directives [2] are focused on the electronics sector. Both are drivers for the manufacture of products with reduced environmental impacts throughout the product's life cycle particularly focusing on facilitating recovery, reuse and recycling at product end of life.

0959-6526/03/$ - see front matter © 2003 Elsevier Science Ltd. All rights reserved.
doi:10.1016/S0959-6526(02)00164-6

need for mainstream, pragmatic approaches to sustainable product development, as well as, to service development. In response, the Sustainable Product and Service Development (SPSD) method is being developed by the authors in conjunction with industry and practitioners. The SPSD approach builds on existing concepts and tools from research and industry. To ensure a practical approach, industry initiatives have been utilised in the development of this method, to include the Irish Environmentally Superior Products (ESP) initiative that is managed by one of the authors of this paper.

This paper introduces the SPSD method and its development and explores how it is used to effectively develop sustainable products and/or services. It incorporates the lessons learned from the research into existing sustainable product development approaches from both the business and academic arenas. Examples from industry are used in this paper to illustrate the SPSD approach and the sustainability and business benefits, which can be achieved.

Section 2 of this paper describes the SPSD approach and method. Section 3 outlines the ESP initiative. Section 4 highlights the main topics and conclusions of the research to date.

2. SPSD approach and method

In this section, the SPSD concept is defined in Section 2.1. Section 2.2 outlines the SPSD Method and 2.3 describes how to implement SPSD in a company(ies) and the key features proposed for effective SPSD implementation.

2.1. What is SPSD?

SPSD is defined here as the process of making products and/or services in a more sustainable way throughout their entire lifecycle, from conception to end of life. The products and/or services are developed to be more sustainable in a Triple Bottom Line (TBL) context [3], i.e. balancing economic, environmental and social aspects. This is interpreted as achieving an optimum balance between environmental protection, social equity and economic prosperity, while still meeting traditional product requirements, e.g. quality, market, technical and cost issues, etc. The goal of SPSD is to produce products and/or to provide services, which are sustainable and achieve their required functionality, meet customer requirements and are cost effective. In other words, SPSD is about producing superior products and/or services that fulfil traditional criteria as well as sustainability requirements. The integration of environment with traditional product criteria to produce superior products is the approach successfully used in the ESP initiative. The results of this initiative illustrate that this integrated approach has business benefits as well as wider sustainability impacts [4]. A summary of this initiative is presented in Section 3.

SPSD is an evolution of existing sustainable product development approaches in that it incorporates services as well as products and all TBL elements. Sustainable product development approaches used in industry to date mainly focus on reducing the environmental impacts of products. This is known as eco-design or Design for Environment and is well established in research terms and is increasingly seen in innovative product manufacturing companies mainly in the form of eco(re)design [5]. There are also Design for '*X*' approaches, which have subsets focused on specific areas, e.g. Design for Disassembly, Design for Recycling, etc. [6]. While a number of terms have evolved for this, these approaches all focus to different extents on identifying and reducing or, where possible, eliminating the environmental impacts of a product throughout its life cycle. In Fig. 1, the Sustainable Product and Services pyramid is introduced to illustrate the evolution of the Design for *X*, eco-design and SPSD approaches towards sustainability. A more sustainable result is likely to be achieved by incorporating the concepts at the top of the pyramid in the SPSD approach. If these are not incorporated, some of the environmental impacts of the product and/or service proposed may be minimised, but greater opportunities for producing a more sustainable product and/or service may not be realised.

Regarding terminology for practitioners, terms and concepts such as Sustainable Product Design and Development [7] and Sustainable Product Development [8–10] are already in use. The SPSD method builds on these existing concepts. SPSD is proposed as a suitable term for the process[3] as it clarifies that the approach is appli-

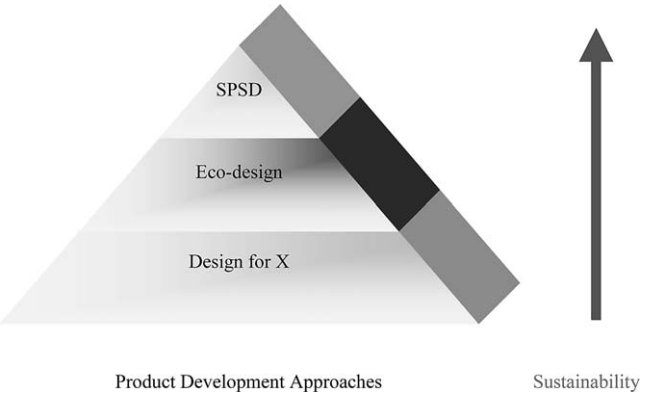


Fig. 1. Sustainable Product and Services pyramid.

[3] The authors acknowledge that SPSD is not a great term for business use as it is long and introduces yet another buzz word! For practitioners SPSD is a suitable term. For business the language should focus on sustainable products and services or other suitable terminology already in the company culture which reflects the same concept.

cable to both products and services as well as incorporating the all-important Product Service Systems (PSS) concept[11,12]. This is about shifting the focus of the design away from producing products to providing a function and determining whether the function can be provided by a service, a product or some combination of a PSS. This approach can have significant environmental benefits in terms of reducing the volume of products manufactured while maintaining or increasing profits for the company through service provision. Examples of companies who have successfully shifted to using a PSS approach include *Xerox* (moving from a photocopier manufacturer to the 'Document Company') and *Electrolux* (moving from an appliance manufacturer to an industrial cleaning service firm)[11,13,14]. Both companies provide 'functions' through a PSS approach, offering a product, which incorporates service elements, e.g. product leasing, upgrade and maintenance to provide the required functionality more effectively.

2.1.1. SPSD and Cleaner Production

SPSD extends Cleaner Production systems by incorporation of all TBL issues (not just environment) and the inclusion of all life cycle phases (product conception to end of life) and forms a new element in the Clean Technology (CT) (or more accurately) 'Sustainable Technology' approach. SPSD is designed to integrate with existing CT approaches, e.g. EMS. Overall, SPSD is a key element of CT for manufacturing industry to manage the sustainability impacts of products and/or services.

2.2. SPSD method

The authors are developing the SPSD method building on their own and other research and industry experiences of sustainable product development. The method is designed to meet the requirements of business and industry in developing sustainable products and/or services and to provide formalised support adding to what is currently available. Lessons learned to date, from the research project propose the following key features as essential framework conditions for ensuring effective SPSD implementation in industry. These features include:

- Use of a strategy level approach, which is integrated into existing corporate business, sustainability/environmental systems and product development systems.
- Use of a simple, flexible, non-resource intensive approach that is designed to mesh with the business reality.
- Integration and optimisation of TBL criteria with traditional product and service specifications over the entire product life cycle.
- Determination of the requirement for a product based on the functionality and consideration of the options for PSS.
- Use of Supply Chain Dynamics (SCD) to determine the most effective target supply chain company(ies) for SPSD implementation and for effective Supply Chain Management (SCM) up and down the supply chain.

These features are described further in Section 2.3.

2.3. SPSD implementation

In this section, the general steps in SPSD implementation are summarised to explain the overall process. Then the key features for effective SPSD are described in more detail.

SPSD is about assessing the lifecycle of a function to be provided (from conception to end of life) and determining the optimum sustainable (environmental, social and economic) way of providing that function (through a product, service or PSS) in line with traditional product and/or service criteria. The product and/or service lifecycle (see Fig. 2) starts at conception where there is only a concept and design of a potential product, service or PSS commences. If a product or PSS is to be produced the remaining stages include raw materials through end of life as well as potential 'recovery' and 'reuse' options illustrated by the dashed lines.

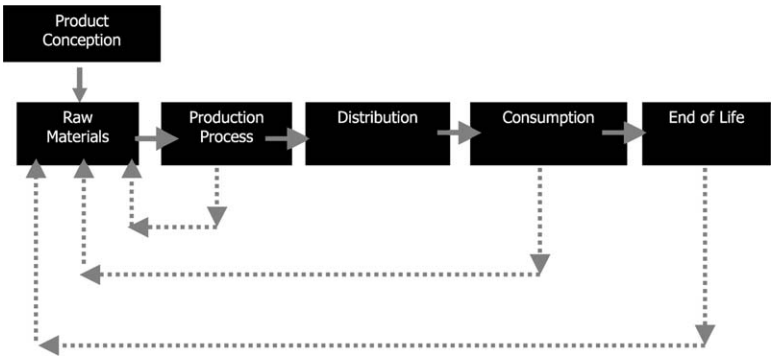


Fig. 2. Product life cycle stages.

SPSD can be applied to an existing product and/or service, but ideally at the concept stage before a commitment to producing a product has been made. With only a concept, greater opportunities for the development of a more sustainable solution may be realised especially regarding environment[8,10,11,15]. Fig. 3 illustrates the main SPSD process steps. Starting at the concept stage, one of the initial steps of SPSD is to consider how the functional requirement can be met—through a product, a service or some combination of a PSS[10,11,12,15] and optimising the sustainability impacts of these options with traditional criteria. The use of SPSD may result in a product not being produced at all. This is in circumstances where it is more sustainable and feasible to meet the required functionality by the provision of a service. In practice, complete replacement of a product by a service is difficult to achieve. Some combination of PSS is a more likely possibility [16].

Once it has been determined whether a product, service or PSS is to be developed, the next stage is to identify the lifecycle stages and associated supply chain, as relevant. A key element of SPSD is that it focuses on the supply chain for the product and/or service rather than solely at an individual company level. The entire supply chain and SCD are assessed to determine the most effective target organisation(s) in the chain for SPSD and how the SCM can be effectively utilised. Once this is determined, SPSD implementation can commence at the company level. Typically, the SPSD implementation occurs at Original Equipment Manufacturer (OEM) level and aspects of it are spread through the supply chain, e.g. through changes in the product and/or service specification. Full SPSD implementation is typically not required by all supply chain companies, just the ones with control over the main life cycle phases with key sustainability issues. However, the input of all relevant supply chain companies into the process (even if solely on an information supply basis) is crucial which is the reason for using SCM to ensure this.

The next step is to assess the environmental and then

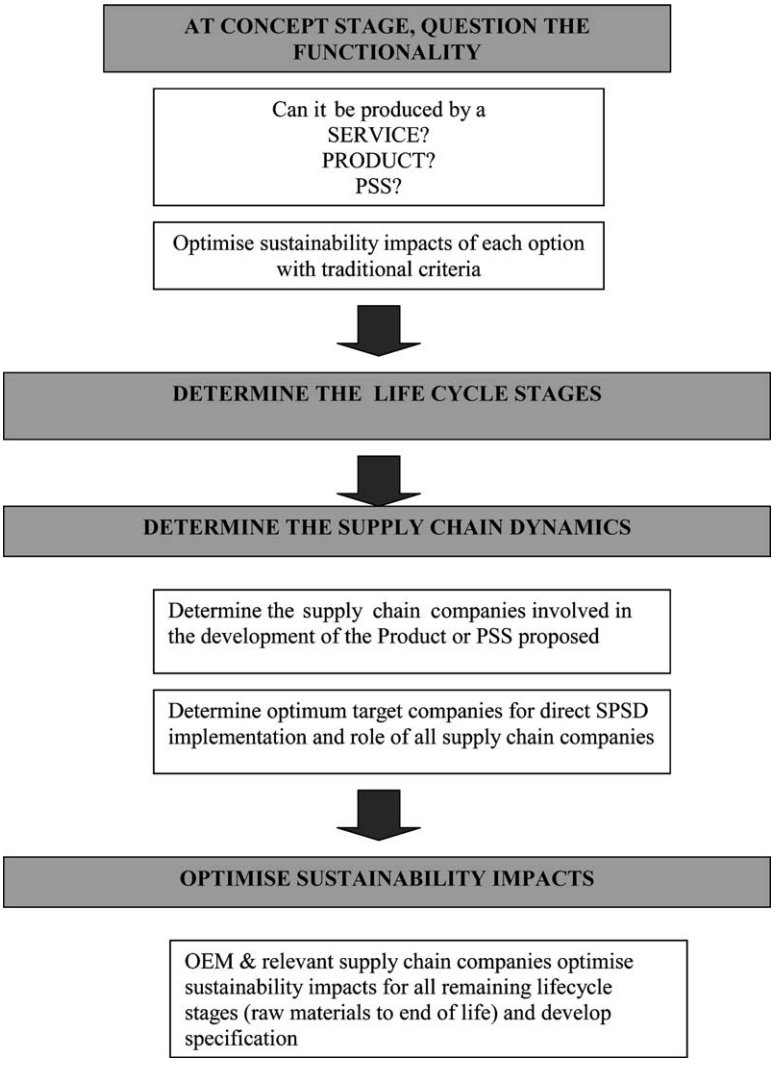


Fig. 3. SPSD process summary.

social impacts for each product or PSS life cycle stage from raw materials to end of life. The opportunities for elimination or minimisation of these are optimised with the remaining traditional product and service criteria. The specific environmental and social issues to be assessed vary dependant on the product and/or service. To ensure a comprehensive approach, a checklist of typical environmental and social impacts to be considered per lifecycle stage is used. Appendix A includes an example checklist of the basic functionality, environmental, social and economic issues which can be considered per lifecycle stage in the SPSD process. It should be noted that a lifecycle 'approach' is used to assess the sustainability impacts for each lifecycle phase. This is not Life Cycle Assessment (LCA) as defined in ISO14040 [17] but a simplified more qualitative approach which incorporates all TBL elements and can be supported by suitable quantitative tools, e.g. abridged LCA if required.

Following on from this summary of the SPSD process, the key framework features for effective SPSD implementation are described in Sections 2.3.1–2.3.5 below.

2.3.1. Strategy level, integrated approach

There is a growing view in the Sustainable Development [18] as well as sustainable product development fields[7,19] that building in sustainability at a strategic level within industry will result in greater improvements in sustainability performance. However, at present most eco-design methods focus at the operational rather than strategic levels[6,7,20]. Further, many existing eco-design approaches are not integrated into product development, let alone into company strategies[9,21] and standard business functions [18].

This research has found that incorporating SPSD into the existing business strategy is necessary for corporate commitment and is more effective for cascading SPSD throughout the company's activities. This was the experience of companies participating in ESP who integrated this approach into their strategy and from there to all business functions relevant to product development and environmental management. Fig. 4 illustrates a proposed structure for this integration.

The requirement to produce sustainable products and/or services as relevant is integrated as one element of the existing corporate strategy (illustrated in the central sphere). From here it is a core business criterion that can be incorporated into all other business functions for overall sustainability performance improvement. In particular, SPSD should be incorporated within the product development (this includes design) approaches used by the company. Other functions that traditionally feed into product development, e.g. quality, finance, purchasing, etc. will then be incorporated more easily with the sustainability criteria. Further, where a company operates a system to manage their environmental (and where included wider social) performance, e.g. EMS, SPSD should be imbedded within it. Some MNCs that have implemented eco-design, have integrated it into their company's existing systems for managing their environmental performance. For example, *Nike* and *IKEA* have integrated eco-design into their TNS (The Natural Step) approach. *Electrolux* and *Philips* include eco-design in their Product Orientated Environmental Management System (POEMS) [20]

Fig. 4. Integrating SPSD into product manufacturer's corporate systems.

Overall, by integrating sustainability in the corporate strategy it is set up as a core element necessary for improving business performance rather than a stand alone programme.

2.3.2. Simple, pragmatic approach

In addition to embedding SPSD into the corporate strategy and integrating it with the company's existing business functions, this research proposes that SPSD will only be effective if it is simple, pragmatic, flexible and is in line with business realities. Research involving *IBM*, *Bristel Myers Squibb* and *Armstrong World Industries* [19], recommended such an approach on the eco-design front. This is even more important for the more holistic SPSD. Further, it should not be overly resource intensive in terms of time, cost or personnel especially in light of the typically short time span from product concept to market [19]. There is a growing recognition that eco-design can be complex, highly quantitative and resource intensive in terms of the expertise, personnel, time and costs incurred for implementation[7,22–24]. Incorporating this view the SPSD method uses a qualitative, pragmatic approach customised to the companies' existing business and product strategies which is supported, where relevant, by suitable quantitative tools, e.g. abridged LCA. This was the approach used for the ESP

initiative and was determined by the respective product or PSS, as well as existing company culture, product development and environmental management approaches. This flexibility in approach was seen as key to companies incorporating and maintaining sustainability criteria in their product and service development processes.

2.3.3. Integration and optimisation of the Triple Bottom Line

The optimisation of social, ethical and economic issues is not included in eco-design in its present form. If sustainability is the aim, just reducing the environmental impact of a product using an eco-design approach is not enough[9,10,21]. In order to effectively integrate sustainability in product and service development, SPSD integrates and optimises sustainability with traditional product critera. The ESP initiative uses this integrated approach and illustrates that optimising environment with other traditional product criteria works on both an environmental as well as business level for companies (see Section 3). An illustration of the proposed criteria to be optimised in developing sustainable products and services is presented in Fig. 5.

In addition to the traditional product criteria, e.g. economic, quality, market, customer requirements, technical feasibility and compliance issues illustrated in Fig. 5, the following sustainability criteria have been incorporated:

- environmental impacts;
- social impacts.

The third TBL element, economics, is already a criterion. Further, in order to effectively optimise the environmental and social impacts the following criterion is included:

- Functionality.

This relates to assessing the functionality required and the options for realising this through a product, a service or a PSS.

2.3.4. Determining the requirement for a product and consideration of options for PSS

The functionality and options for PSS are considered at the product conception phase. This incorporates dematerialisation, whereby, the material and energy inputs into a product are reduced or replaced completely by an immaterial substitute for complete dematerialisation [16]. In reality, it is difficult to achieve complete dematerialisation and still achieve the end product function. However, a combination of a product and service approach that reduces the product element is possible and has been achieved to environmental and commercial benefit by some companies. For example, in 2000, *Xerox* reduced their product material inputs by approximately 72,000 ton with an associated US$ 27 million savings [13].

The PSS approach decouples volume (producing lots of products) from profitability and focuses on the functionality, i.e. producing less product and managing it better as a PSS. Value is based on functionality, not on materials content. The environmental benefits resultant from the PSS approach can include:

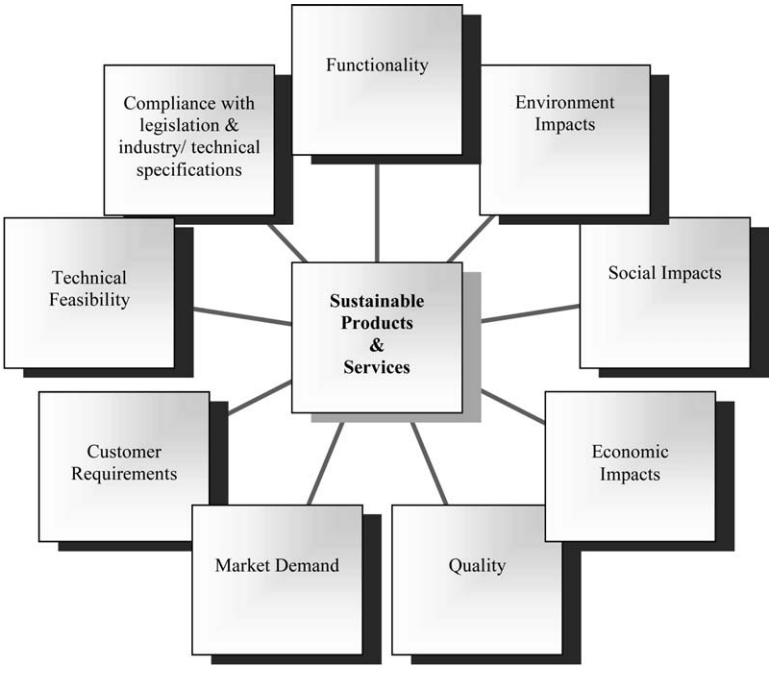


Fig. 5. Criteria for optimising sustainability in products and services.

- a reduction in the volume of products produced;
- increased dematerialisation of product;
- reduced waste generation due to the reduced volume of products produced as well as the eco efficiencies introduced into the production process.

There are also social impacts associated with PSS. For example the replacement of a product by a service can have implications in terms of employment for company personnel at many lifecycle stages.

To date, industry tends to implement an eco(re)design approach whereby they start with an existing product and reduce its environmental impacts [7]. With the exception of a minority of companies, the need for a product based on the functionality required and the options for PSS are not generally considered. Leaving this step out may result in the application of environmental improvement measures to a product which is inherently unsustainable, whereas the optimum sustainable solution would have been not to produce a product but say a service, or a combination of both in the first place[10,15]. Questioning the requirement for a product and consideration of alternative options to meet a functional requirement is an essential component of SPSD.

Fig. 6 illustrates how the options for sustainability are increased as one moves from standard eco-design criteria that incorporate environmental impacts alone to incorporation of social impacts and incorporation of the functionality and options for PSS.

2.3.5. SPSD and the product supply chain

To date, most approaches for reducing the sustainability impacts of products, e.g. eco-design, are aimed directly at individual companies irrespective of their role in the supply chain and the wider product SCD. Further, there is a trend towards developing eco-design and Sustainable Product Development tools in line with company size, e.g. large or small and medium sized enterprise (SME) in line with traditional environmental improvement approaches. This research proposes a different approach.

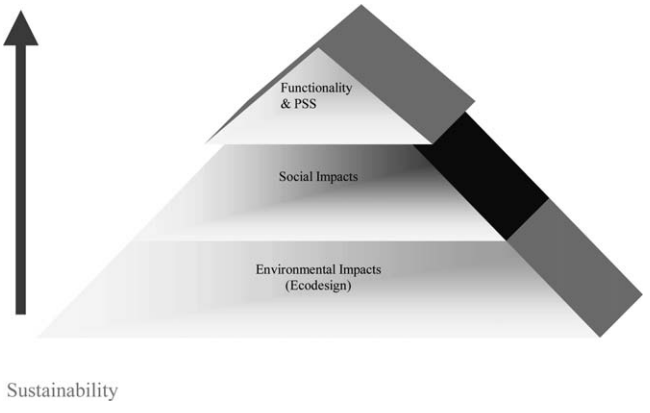


Fig. 6. SPSD pyramid to illustrate how increased sustainability results from incorporating the criterion as one moves up the pyramid.

In order to effectively reduce the sustainability impacts of products, the supply chain aspect of product manufacture needs to be incorporated. With the exception of products manufactured in a direct business to consumer relationship, most products with significant sustainability impacts, e.g. cars or electronics goods, are manufactured using a number of companies involved in a supply chain. Typically, this will involve an OEM and a range of component suppliers, subcomponent suppliers (to many tiers potentially) and assemblers. Typically the OEM has control over the product and/or service design and specification. The other companies, in the supply chain, supply and/or assemble their elements in line with this. In light of this, it is proposed that the supply chain for a proposed product and/or service must be considered in order to determine which company (ies) within the supply chain will be the most effective targets for SPSD as well as its different aspects. Further, it is necessary to target the organisations with control over the product life cycle stages where most sustainability issues can be most effectively tackled—typically the product conception and design phases. It is at these stages, that most (up to 80%) of the environmental, social and cost factors for a product are determined [7]. Hence, it is at this stage that truly effective improvements[4,24] can be made not only in terms of sustainability issues, but also potentially in terms of cost. Examples of this were illustrated in the ESP initiative (see Section 3).

Overall, determining the most effective target organisations for SPSD is a crucial element, which is largely left out of sustainable product development approaches as well as broader environmental performance improvement measures in industry to date [25]. A growing number of experts, view this as missing and that it is important not only for effective eco-design implementation[19,20,26–28], but also for achieving environmental improvements in companies, in general[29,30].

There is a trend towards targeting environmental performance improvement methods at organisations based on their size. For example much work has been done to formulate environmental performance improvement approaches, to include eco-design, specifically to engage and meet the needs of SMEs. It is reasonable to apply environmental performance improvement systems, e.g. EMS directly to SMEs as SMEs have control over activities at their production facilities and can manage their environmental impacts. However, the same rationale is not necessarily relevant for products as many companies, especially SMEs, may not have this control and need to work in conjunction with the OEM to change the product specification.

This research proposes that irrespective of company size (large or SME), SPSD will be more effective if targeted at the organisations that have control over key pro-

duct life cycle stages, particularly the conception and design phases. It is proposed to move the focus away from the size of the company (large or SME) to incorporation of the SCD relevant to the product supply chain. The SPSD approach may then be spread out to other organisations involved in the supply chain either upstream or downstream as relevant mainly in the form of product specifications. It is proposed that through this approach, the roles of large and SME organisations in making product systems more sustainable, can be most effectively utilised. Using this approach, SPSD may be applied through the supply chain involving a permutation of large and SME organisations,depending on the SCD. This shift in focus away from an individual company towards the product supply chain could lead to a paradigm shift in how we apply sustainability approaches in product manufacture. The ESP initiative illustrated the importance of focusing on the supply chain. In this initiative supply chain companies for a respective product worked in conjunction with each other and in particular this involved the company(ies) with control over the key lifecycle stages and the product specification. Without participation of all relevant supply chain companies in their specific roles sustainability improvements to the product would not have been as effective.

3. Environmentally Superior Products

This section outlines the ESP initiative, the sustainability and business benefits resultant and case examples.

ESP is an Irish initiative run by the *Environment Unit* of *Enterprise Ireland*, a government agency responsible for supporting the development of Irish industry. The ESP initiative provides financial and other support (information, advice, networking) to manufacturing industry to incorporate environmental concepts in their product development process. Typically, ESP projects assess ways to reduce the environmental impacts of a product(s) and/or service(s) without compromising its functionality, quality, ability to manufacture or cost. This results in what is defined as an 'Environmentally Superior Product'. The aim of the initiative is to improve the environmental and hence business performance of Irish manufacturing industry through a more sustainable approach to product and/or service development.

An ESP pilot initiative was conducted from 1999 to 2001 during which 12 companies participated from a range of manufacturing industry sectors (e.g. electronics, IT, construction, packaging, furniture and timber) and playing different roles in the supply chain (e.g. component or subcomponent suppliers to OEMs). While each ESP project varied, the following elements were incorporated:

- *Strategy approach*: The ESP approach was integrated within the company's strategy, product development and EMS, as relevant.
- *Simple, flexible approach*: A simplified life cycle approach suited to the company culture was used to assess the environmental impacts. This varied from use of checklists to use of abridged LCA.
- *Integration and optimisation of environment with traditional product criteria; questioning the functionality and considering options for PSS*: In each ESP project, the potential ways of eliminating (where possible) or reducing the environmental impacts while still meeting the required traditional criteria were assessed using a life cycle approach. The feasibility of each environmental impact elimination/reduction option was analysed in terms of the following criteria (not in order of priority):
- functionality and options for PSS;
- customer requirements;
- quality;
- market demand;
- technical feasibility;
- compliance with relevant environmental policy/ regulatory requirements;
- compliance with relevant industry/technical specifications, e.g. CE marking;
- third party product validation options, e.g. eco labels;
- economic issues, e.g. cost.

The design that optimised all the criteria was considered the environmentally superior option.

- *Focusing on the supply chain*: Participants in an ESP project typically involve companies in the product supply chain from raw material component suppliers to OEMs. An important step in each ESP project was to assess the individual companies' influence on possible design changes to a product.

3.1. Sustainability and business benefits

Overall sustainability as well as business benefits were realised from the ESP projects. In the main the environmental impacts of new or existing products were reduced. The reduced environmental impacts varied per product and/or service but included dematerialisation through a PSS approach as well as a range of eco-efficiencies, e.g.

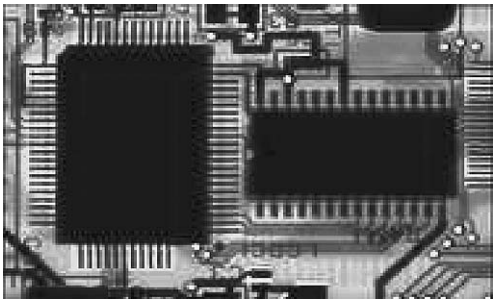
- reduced volume of raw materials;
- eliminated and/or reduced hazardous raw materials usage;
- reduced energy usage;
- eliminated/reduced waste generation.

As environmental impact reduction was the key focus of this initiative, only limited social impact reduction was realised (mainly relating to in plant social issues). In terms of other business benefits, improved product and/or service functionality, cost savings, competitive advantage, new business opportunities, capability building, improved supplier relationships and corporate reputation were all realised. In those projects involving a redesign of an existing product, the companies found that by reducing the environmental impact, the product functionality was improved and it was 'cleaner' and cheaper (except for one which was the same cost) to produce. These additional benefits all added to the overall 'superior' nature of the product and/or service. On this basis, a number of commercial, as well as environmental successes, were achieved by the participants of the initiative. In particular, for two companies, the ESP resultant from the initiative, have substantially increased the company's sales and exports [4]. Participant companies experienced improved supplier relations, with two companies achieving preferred supplier status for their products over competitors who were not able to provide such a sustainable option. All companies reported capacity building benefits in terms of knowledge and expertise. The ESP initiative highlights the business success that can be achieved when environment is integrated and optimised with existing product criteria. Examples of some of the ESPs developed include:

- electronic circuit boards with a reduced materials content and increased energy efficiency;
- computers with an extended life as well as increased reuse/recycling options at end of life;
- recyclable, reusable toner cartridges;
- office chairs designed to be disassembled and upgraded to extend operational life as well as maximising reuse/recycling options at eventual end of life;
- reusable, returnable packaging for the microelectronics sector;
- outdoor recycled plastic furniture manufactured from reclaimed healthcare waste plastics.

Two ESP case examples are outlined below.

Case Example 1. Electronic automotive components (see figure below).



In this project an environmentally superior electronic Remote Keyless Entry unit for cars was designed. The project involved the SME manufacturer of the component working in conjunction with supply chain companies from raw material suppliers to OEM customer. The environmental improvements achieved included:

- dematerialisation of the unit's circuit board components by 40% to include the reduction of hazardous substances;
- threefold reduction in energy usage.

As a result of these environmental improvements, the product was quicker and more cost effective to manufacture resulting in substantial cost savings and competitive advantage for the company and their customer.

Case Example 2. Personal computer (see figure below).

In this project an OEM computer manufacturer worked with supply chain companies to develop a PSS for environmentally superior computers. The PSS involved the provision of a modular, upgradable computer with upgrade and maintenance service elements provided. Environmentally the main benefits included:

- use of raw materials and assembly techniques to increase the reuse and recycling options at end of life;
- extending the operational life of the hardware (up to a potential 5 years longer than standard computers) via an upgradeable chassis with interface modular port design and upgrade and maintenance service elements;
- increased energy efficiency.

A case study publication of the ESP pilot projects is available from Enterprise Ireland [31].

4. Summary and conclusions

Industry is under growing pressure from legal and market drivers to adopt a more sustainable approach to product design and manufacture. To support this industrial requirement, this paper introduces the SPSD approach and method currently being developed at *Imperial College London*. SPSD is proposed as a pragmatic, industry friendly, approach for developing sustainable products and/or services that can be integrated with existing CT approaches. The SPSD method is designed to provide a framework for implementing SPSD throughout the complete lifecycle of a product and/or service and the associated supply chain. The method is designed to identify, assess and implement the options for optimising sustainability in product and/or service development.

As part of this approach, the following features are proposed as essential for effective, practical SPSD implementation:

- utilising a strategy level approach, which is integrated into existing corporate business, product development and sustainability/environmental systems.
- Employing a simple, flexible, non-resource intensive, practical approach designed to mesh with business reality.
- Integrating and optimising the TBL (environment, social and economic) with traditional product and service specifications over the entire product life cycle.
- Determining the requirement for a product and considering the options for PSS.
- Using the product SCD to determine the most effective target company(ies) for SPSD and for effective SCM up and down the supply chain. This represents a shift in focus from the individual company to the product supply chain.

Overall, SPSD is about developing superior products and/or services that fulfil traditional product criteria as well as the sustainability requirements. Early testing of the SPSD approach in industry indicates that the features proposed work effectively in practice and provide a practical approach to companies for producing sustainable products and/or services. In particular, existing industry case studies from the ESP initiative, illustrate that effective SPSD implementation is a WIN–WIN situation resulting in business as well as sustainability benefits up and down the supply chain.

Acknowledgements

The authors gratefully acknowledge the support of the Elsie Widdowson Fellowship programme.

Appendix A

The SPSD checklist below is a guide to the TBL issues to be considered in the development of a sustainable product and/or service. This checklist contains generic examples which are suitably customised in each situation.

SPSD criteria	Life cycle	Issues to consider (as relevant)
Optimise functionality	Conception	What is the functionality?
		How can this be achieved?
		Do you need a product?
		Could this be achieved by a service?
		Options for PSS?
Optimise environmental impact	Raw materials	Reduce the volume of materials used (dematerialisation)
		Nature of raw materials
		Eliminate or reduce non-renewables usage

		Substitution of none/less hazardous raw materials
		Facilitate recovery, reuse, recycling
		Extraction and processing of raw materials
		Transport from supplier
	Production	Optimise production technology
		Eliminate/reduce emissions to air
		Eliminate/reduce effluents
		Eliminate/reduce waste
		Eliminate/reduce energy usage
	Distribution	Is transport necessary?
		Volume and nature of transport
		Type of fuel usage
		Eliminate/reduce emissions to air
		Eliminate/reduce waste
	Consumption	Eliminate/reduce waste from product
		Eliminate/reduce waste from packaging
		Eliminate/reduce energy consumption
	End of life	Extend product life
		Design for repair
		Modular design for maximising upgradability
		Facilitate recovery of components for reuse
		Facilitate recovery of components for recycling and treatment/disposal
Optimise social impacts	Raw materials	Are the raw materials extracted/processed in the developing world?
		Ownership rights
		Are the trading arrangements equitable?
	Production and distribution	Employee conditions of work at company
		Employee conditions of work in subcontract companies
		Impact on local community
		Investment in local community
	Consumption	Adverse health/safety impacts for the local community
		Adverse health/safety impacts for the global community
	End of life	Adverse health/safety impacts for the local community
		Adverse health/safety impacts for the global community
Optimise economic aspects	All phases	Is the product and/or service cost effective?
		Does the product and/or service cost the same/less than competing versions?
		Are environmental externality costs (e.g. end of life recovery, reuse/treatment/disposal) taken into account?

References

[1] EC. Council Directive 2000/53/EC on end-of life vehicles. Brussels, 18/09/2000, OJ L269, 21/10/2000. p. 34–43.

[2] EC. Proposal for a directive on waste from electrical and electronic equipment COM(2000) 347-1 and COM(2002) 353 and proposal for a directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment COM(2000) 347-2. Brussels, 2000/0158 (COD), 2000/0159 (COD).

[3] Elkington J. Cannibals with forks, the triple bottom line of 21st century business. UK: Calstone Publishing Limited, 1997 [ISBN 1-900961-27-X].

[4] Maxwell D. Environmentally Superior Products—a commercial and environmental success story. Ireland: Environment and Energy Management; August 2001. p. 7–13.

[5] Gertsakis J, Lewis H, Ryan C. A guide to EcoReDesign. Australia: Centre for Design at RMIT, 1997 [ISBN 0864446500].

[6] Simon M, Evans S, McAloone T, Sweatman A, Bhramra T, Poole S. Ecodesign Navigator EPSRC. UK: Deanprint, 1998 [ISBN 871315-74-3].

[7] Charter M, Tischner U. Sustainable product design. In: Sustainable Solutions. UK: Greenleaf Publishing Ltd; 2001. [ISBN 187419365].

[8] Hanssen OJ. Sustainable industrial product systems. Norway: Stiftelsen Østfoldforskning, 1997.

[9] Byggeth SH, Broman G, Holmberg J, Lundqvist U, Robèrt K-H. A method for sustainable product development in small and medium sized enterprises. In: TMCE—Tools and Methods of Competitive Engineering, Symposium, Delft, the Netherlands, 18–21 April. 2000.

[10] van Weenen H. Product design–practical examples of SMEs. In: Proceedings in Sustainable Development, SMEs and New Enterprises, European Foundation, Ireland, 12–13 October. 2000.

[11] Reiskin E, White A, Kauffman J, Votta J. Servicizing the chemical supply chain. J Ind Ecol 2000;3(2–3).

[12] Mont O. Lessons from the transitions towards product–service systems in Swedish companies: reflections and methodologies. In: Proceedings of Sustainable Services and Systems: Transition Towards Sustainability? Towards Sustainable Product Design No. 6, The Netherlands, 29–30 October. 2001. p. 184–94.

[13] Xerox Corporation. Environment, health and safety report. 2001, UK and USA Xerox Corporation; 2001.

[14] Electrolux. Environment report 2001. Sweden: Electrolux; 2001.

[15] Brezet H, van Hemel C. Ecodesign, a promising approach to sustainable production and consumption. France: United Nations publication, 1997 [ISBN 92-807-1631-X].

[16] van Hemel C. Ecodesign empirically explored. In: Design for environment in Dutch SMEs. Amsterdam: Boekhandel Milieu-Boek; 1998. [ISBN 90-9011667-2].

[17] ISO. ISO14040, Environmental management—life cycle assessment—principles and framework. Switzerland: ISO; 1998.

[18] SustainAbility. Website for SustainAbility http://www.sustainability.co.uk/home.asp (accessed 04/05/01).

[19] Shapiro K, White A. Pathway to product stewardship: life-cycle design as a business decision-support tool. Report to the US EPA. Tellus Institute; November 1997. p. 1–2.

[20] Croner. Environmental management systems and eco-design. Croner special report. Practical guidance on environmental management. Issue No. 50; 14 February 2000. p. 1–8.

[21] Byggeth SH, Broman G. Environmental aspects in product development—an investigation among small and medium sized enterprises. In: SPIE International Symposium on Intelligent Systems and Advanced Manufacturing; Environmentally Conscious Manufacturing, Boston, USA, 5–8 November. 2000.

[22] van der Vorst R, Grafé-Buckens A, Sheate W. A systematic framework for environmental decision making. J Environ Assess Policy Manage 1999;1(1):1–26 [UK: Imperial College Press].

[23] Holmberg J, Lundqvist U, Robèrt KH. An approach to sustainable product development relevant to small and medium sized enterprises. In: Hillary R, editor. Small and medium-sized enterprises and the environment business imperatives. UK: Greenleaf Publishing Ltd; 2000. [ISBN 1874719225].

[24] Datschefski E. Website of Greenerbydesign, http://www.biothinking.com/index.htm (accessed 30/08/00).

[25] Laurent S, Duckers L. SMEs and the environmental challenge: muddling through the systems dynamics of the innovation process. In: Proceedings of Sustainable Development SMEs and New Enterprises, European Foundation, Ireland, October 12–13. 2000.

[26] Charter M, Young A, Kielkiewicz-Young A, Belmane I. Integrated product policy and eco-product development. In: Sustainable solutions. UK: Greenleaf Publishing Ltd; 2001. [ISBN 187419365].

[27] Tischner U. Eco-design tools. In: Proceedings at Eco-design and Supply Chain Management, UK, 28 June. 1999.

[28] Morton B. Environmental supply chain forum: CROMTEC. In: Proceedings of Eco-design and Supply Chain Management, UK, 28 June. 1999.

[29] UNEP. UNEP environmental management tools supply chain management. Available from website http://www.unepie.org/pc/pc/tools/supplychain.htm (accessed (04/02/2002).

[30] US EPA. The lean and green supply chain: a practical guide for materials managers and supply chain managers to reduce costs and improve environmental performance. US, EPA 742-r-00-001. p. 1–58.

[31] Enterprise Ireland. Improving your business through the environment. Environmentally Superior Products pilot demonstration initiative case studies. Ireland: Enterprise Ireland; 2001.

Dorothy Maxwell, BSc (Hons), University College Dublin, Ireland, 1989; MSc, DIC (Environmental Technology), Imperial College Centre for Environmental Technology, University of London, UK, 1992, has worked in the environmental arena for over 12 years in mainstream environmental consultancy to the public and private sectors. Her specialist areas of expertise include CT, Cleaner Production, Environmental Management Systems, Waste Minimisation and Sustainable Product Development. A native of New York City, she has worked as an environmental specialist in Europe, USA and Asia with international consultancies *Andersen Consulting* (now *Accenture*) and *Willis Corroon Group*. Currently based in the *Environment Unit, Enterprise Ireland*, she provides environmental expertise to business and industry and is managing the first Irish Sustainable Product Development initiative *Environmentally Superior Products (ESP)*. She currently combines her professional work on *ESP* with a PhD research project on SPSD with the *Environmental Policy and Management Group (EPMG), Environment Science and Technology Department, Imperial College, University of London*. She has produced a range of environmental publications for *Business and Finance*, the *European Commission*, *Environmental Protection Agency* and *European Institute of Environmental Policy*. She regularly lectures on environmental topics to industry and is a visiting lecturer on the Environmental Technology MSc at *Imperial College, University of London*.

Rita van der vorst, Dipl.-Ing. (Mech. and Process Engineering) University of Technology, Aachen, 1991; PGD Education, Brunel University, 1994; PhD Brunel University, 1997, is senior lecturer in Clean Technology in the Department of Environmental Science and Technology and acts as the Deputy Director for the MSc in Environmental Technology and as Option Convenor for the Pollution Management strand of the Course. Before joining Imperial College in 1996 she worked as a lecturer at Brunel University where she developed and ran an undergraduate engineering programme with industry input focusing on environmental preventative engineering. Her research in Clean Technology mainly focuses on environmental systems design, including industrial ecology and permaculture and organisational development. It also addresses waste minimisation, environmental product and process design, LCA and environmental management.