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Jairo da Costa Junior, Ana Laura Rodrigues dos Santos and Jan Carel Diehl

Introducing systems-oriented design for complex societal contexts in design engineering education

Abstract
Faced with large-scale wicked problems that include global warming, resource depletion, poverty and humanitarian emergencies, society needs new and more appropriate reasoning models. In particular, these problems pose unfamiliar challenges in contexts with poor financial and infrastructural resources. Systems-oriented design (SOD) is widely recognised as one promising approach that can support design engineers in addressing these complex societal problems. This paper explores the application of SOD in the development of product-service system (PSS) concepts by student teams in a multidisciplinary master course. The resulting twelve concepts were analysed using a case study approach and protocol analysis, describing the advantages and context- and process-related challenges of using SOD. From an educational perspective, the results demonstrate that while SOD provides students with a broad knowledge base and skills for addressing problems in complex societal contexts, there remains a need to introduce appropriate scope and depth to the design engineering curricula, making the transition from traditional product design a challenging one.

Keywords: systems-oriented design, socio-technical system, product-service system, complex societal context, low-income energy market, humanitarian aid, sustainability

Introduction

Humanitarian organisations, governments and companies face major challenges in providing essential services such as energy and healthcare in contexts with poor financial and infrastructural resources. As stakeholders in these complex societal contexts often create an informal market and use unconventional methods for product distribution and servicing which, in most cases, customers or end-users cannot afford, alternatives to traditional business and social relations are required for the successful provision of goods and services (Nielsen & Santos, 2013). Additionally, in such resource-limited contexts, the complexity and ambiguity of stakeholders' interests is higher than in traditional businesses (Matos & Silvestre, 2012), and the end-user is generally considered a passive recipient, depending on their own coping mechanisms to benefit from the products and services provided.

In addressing complex societal problems from a product-service development perspective, there is evidence that a systems thinking approach—also known as systems-oriented design (SOD)—is likely to achieve better and more sustainable results than traditional product-service development (Jones, 2014; Sevaldson, Hensel, & Frostell, 2010; Sevaldson, 2008, 2009, 2013). This skills-based approach seeks to develop better design, visualisation and systems practices to create a new generation of design professionals who are equipped to cope with increased complexity (Sevaldson et al., 2010; Sevaldson, 2011, 2013). SOD takes account of different system hierarchies within a given socio-technical system, which is a cluster of elements such as technologies, policies, user practices, markets, culture and infrastructure, linked together to attain a specific functionality within a system (Geels, 2005). SOD promotes change at multiple levels: at the micro-level through individual actions, at the macro-level through organisational arrangements and at the mega-level through societal trends (Elzen, Geels, & Green, 2004).

Design engineers have traditionally relied on a classical model of thinking, characterised by reductionism and rationality. Although this reasoning model is the basis of modern science, its assumptions have proved less effective in dealing with complexity (Gershenson & Heylighen, 2004; Nelson, 2007), and a broader perspective such as systems thinking is needed to address these limitations. For instance, in isolating the components of a given socio-technical system, a reductive analysis is likely to destroy the connections between those components, making it difficult to understand and describe the behaviour of the system (Gershenson & Heylighen, 2004). By adopting SOD, design engineers can handle a larger degree of complexity and make more sustainable changes by considering value creation within a long-term timeframe involving a larger network of stakeholders (Jones, 2014; Sevaldson, 2010). In contrast, relying solely on existing product-service development knowledge (i.e. methods, tools and techniques) restricts the design process creating an inability to understand the local context (London & Hart, 2004).

By broadening the scope and complexity of design practice, SOD increases the capacity of the socio-technical system to function and to achieve sustainability (Reinders, Diehl, & Brezet, 2012; Sevaldson et al., 2010). In a complex societal context, (re)designing products to be affordable is not in itself enough to ensure their adoption for comprehensive accomplishment of the system's function (Brezet, 1997; Gaziulusoy, Boyle, & McDowall, 2011). For that reason, a radical paradigm shift is needed in how we educate future design engineers (Cardenas et al., 2010; Raduma, 2011; Sevaldson, 2008). SOD proposes the design of a coherent combination of processes and product-services to fulfil that function, leading problem solvers to look beyond technology to consider aspects such as business, lifecycle and stakeholder motivations (Baines et al., 2007; Vasantha, Roy, Lelah, & Brissaud, 2012). As design engineers and researchers are typically educated to apply traditional product-service development approaches, higher education institutions (HEIs) become essential partners for system change in this novel innovation network (Vezzoli, Ceschin, & Kemp, 2008).

HEIs play a crucial role in the introduction of knowledge and skills for dealing with complex societal problems. According to Raduma (2011), there is both a strategic opportunity and a challenge for these institutions in rethinking design engineering education to build capacities beyond the creation of products and services. For Raduma, design engineering students are increasingly tasked by industry and the service sector to develop projects that will promote enormous societal change. To address this challenge, HEIs must lead a radical shift in how students are educated, including new pedagogical methods and skills (Cardenas et al., 2010; Raduma, 2011; Sevaldson, 2008; Vanpatter & Jones, 2009). The present study explores the role of HEIs in the transition from traditional product-service development to SOD for complex societal contexts.

This study builds on the work of Santos (2014), in which SOD was proposed as a means of addressing complex problems in challenging societal contexts, especially in the provision of healthcare services in humanitarian aid. The purpose of this study is to build an understanding of how SOD can support design engineering students in developing more sustainable product-service system (PSS) concepts for low-income markets and humanitarian aid. The paper describes the use of HEIs as a base for knowledge transfer between multiple stakeholders in emerging economies when addressing the need for affordable energy in low-income households and humanitarian provision of medical equipment and cold chain monitoring of vaccines and medicines. The study was conducted as part of an elective course called Product-Service Systems in the Industrial Design Engineering Master Programmes in the Faculty of Industrial Design Engineering at Delft University of Technology (TU Delft), in collaboration with the Federal University of Paraná (and partners) in Brazil, and the Innovation Unit of Medécins Sans Frontières (MSF) Sweden.

The paper is structured as follows. The next section presents an overview of the relevant literature on complex societal contexts, PSS and SOD. The research methodology is then described, followed by a detailed account of data collection and analysis. The main findings are then presented, and the advantages and challenges of applying the proposed approach are discussed. The paper concludes with implications for future studies and impacts on design engineering education.

Designing products, services and systems for complex societal contexts

Product-service development in complex societal contexts such as low-income markets and humanitarian aid situations has received little attention in the literature (Betts & Bloom, 2014; Viswanathan & Sridharan, 2012), which has tended to focus both theoretically and empirically on mid- and high-income contexts. To properly address large-scale wicked problems in contemporary society, design engineers must overcome this knowledge gap and apply new models of reasoning (Cardenas et al., 2010; Tatham & Houghton, 2011; Tischner, 2006). The present study argues that the socio-technical regime is significantly different across these contexts. A socio-technical regime comprises a set of rules for complex design engineering practices, such as production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and human resources and ways of defining problems, all of which are embedded in institutions and infrastructures (Elzen et al., 2004).

There is evidence that many products and services have failed to meet the needs of low-income markets because of a failure to understand the local context (Chavan, Gorney, Prabhu, & Arora, 2009; Hanna, Duflo, & Greenstone, 2012; London & Hart, 2004). It has been suggested that the traditional product-service development knowledge associated with mid- and high-income contexts is unsuited to the generation of innovative solutions for complex societal contexts (Chavan et al., 2009; Mahajan & Banga, 2005; Viswanathan & Sridharan, 2012). This existing knowledge base (e.g. traditional approaches, methods, tools and techniques) restricts the design process and limits designers' ability to understand and address the constraints and complexity of low-income contexts (London & Hart, 2004), where everyday life is a distinct physical and mental environment (Hart & Sharma, 2004) and users' needs are shaped by psychological, physical, economic and social necessity. In these conditions, behaviours and habits related to a product or service tend to be profoundly influenced by local norms, beliefs and/or circumstances (Viswanathan & Sridharan, 2012).

Humanitarian emergencies such as natural disasters or conflicts have a particularly strong impact in low-income markets because of contextual vulnerabilities. In particular, the number and types of humanitarian organisations supporting relief and reconstruction activities add to the complexity of the context by creating a parallel market (Binder & Witte, 2007), in which products and services ranging from basic sanitation to complex healthcare initiatives are provided through intricate collaborations of donors, private services and various government and non-government organizations. In these circumstances, the development of products and services must overcome a number of unfamiliar constraints not often found in mid- and high-income contexts (see Table 1, next page).

Designing long-term PSSs in complex societal contexts requires design engineers to change the intrinsic characteristics of products and services. This task demands radical transformations in the expectations, values and cultures embedded in the relation between products and humans, and new ways of understanding the role of product and services (Cardenas et al., 2010). Despite their extensive technological knowledge and technical skills in solving complex problems, designers and engineers commonly have a limited understanding of complex societal contexts, and they are unfamiliar with many of the practicalities of these contexts and associated product-service requirements. SOD can equip design engineering students to develop solutions with the appropriate scope, depth and feasibility to address complex societal problems.

Table 1: Challenges faced in product-service development for complex societal contexts.

Constraints	Examples	Authors
User	Illiteracy; low literacy; functional illiteracy; lack of empowerment; behavioural constraints; unknown cultural norms	(Boeijen & Stappers, 2011a, 2011b; Mays, Racadio, & Gugerty, 2012; Ramalingam, Scriven, & Foley, 2009; Schäfer, Jaeger-Erben, & Santos, 2011; Viswanathan & Rosa, 2007)
Technical	Lack of infrastructure and maintenance	(Crul & Diehl, 2006)
Regulatory	Restrictive or missing regulations, laws and policies	(Mahajan & Banga, 2005; Webb, Kistruck, Ireland, & Ketchen, Jr., 2010)
Institutional	Misalignment of priorities and agendas amongst stakeholders; issues of trust	(Francois, 2002)
Socio-ethical	Lack of equity and social cohesion; exclusion of minority	(Cozzens, 2012; Margolin, 1995; Penin, 2006; Rocchi, 2005; Tischner & Verkuijl, 2006)
Economic	Affordability; limited access to credit; informal economy; poverty penalty	(Prahalad & Ramaswamy, 2004; Webb et al., 2010)
Environmental	Environmental impacts; rebound effects; lack of environmental awareness	(Arnold & Williams, 2012)

Source: Compiled by the authors.

Systems thinking in product-service system design for complex societal contexts

Achieving or maintaining high levels of sustainable socio-economic development in complex societal contexts requires major changes in existing patterns of production, distribution and consumption, with radical solutions that go beyond traditional product-centred innovation (Brezet, 1997; Sevaldson, 2013). Such solutions depend on a broader innovation perspective that considers policy choices, infrastructure change, product-service technology and consumer behaviour. Figure 1 provides an overview of approaches to designing sustainable products, services and systems.

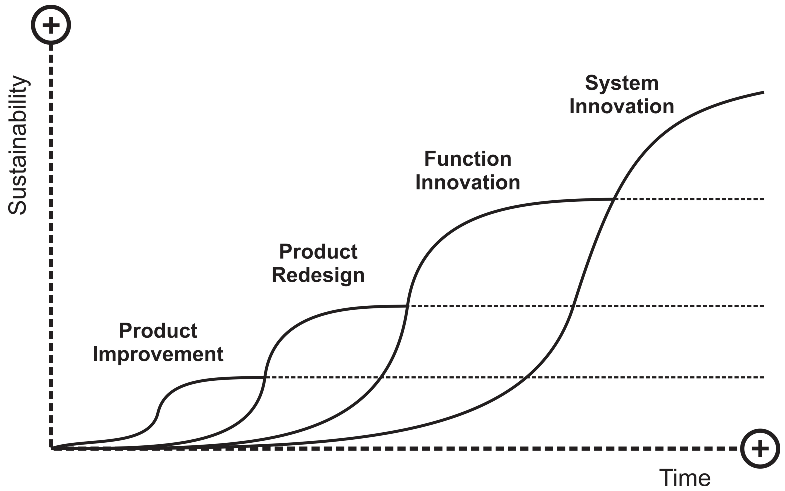

Figure 1: Levels of innovation for sustainability. Source: Brezet (1997).

To meet this increasing need for system innovation, SOD provides a holistic approach that brings systems thinking to design thinking and practice (Sevaldson, 2009). This novel approach takes account of the total societal system and its relations and interconnections as a basis for innovation, combining needs and opportunities to tackle environmental, social-ethical and economic challenges and to improve the effectiveness and sustainability of the total system (Joore, 2008). SOD is best understood as an orientation in which design engineers apply modern systems theory to design practice (e.g. soft system methodology and critical systems thinking) (Sevaldson, 2011), grounding design theory in system theory (e.g. PSS and service design).

The features of a systems thinking approach such as PSS can stimulate progress towards sustainability in complex societal contexts (Penin, 2006; UNEP, 2002; Vezzoli et al., 2014). PSS is a system of products, services, supporting networks and infrastructure, closely involving final consumers and stakeholders in the value chain and beyond, which is designed to be competitive and to satisfy customer needs with lower environmental impact than traditional business models (Mont, 2002a). To strengthen the systems thinking orientation of PSS and so enhance its capacity to deal with complexity, the present approach embeds SOD into PSS development.

PSS shows promise as a solution capable of stimulating the changes in current production and consumption patterns necessary for an environmentally sound socio-economic development trajectory (Manzini & Vezzoli, 2003; Mont, 2002b; UNEP, 2001, 2002). According to UNEP (2002), PSS can provide a higher level of well-being at lower cost through higher system efficiency. These innovative solutions can help to promote more sustainable lifestyles and strengthen awareness of the environmental, social-ethical and economic consequences of production and consumption of products and services. Given that a considerable number of sustainable technologies already exist, the short- and long-term effectiveness of such innovations relies largely on their affordability and how they are introduced to the market (Reinders et al., 2012).

PSS combines a range of comprehensive products, services and systems to provide access to affordable, reliable and clean design solutions. For instance, in the context of low-income energy markets, the electricity sector could benefit from sustainable PSSs such as pay-per-use systems, solar photovoltaic off-grid solutions for remote areas and combinations of energy-related products and services to support income generation in low-income communities. The characteristics of PSS change with the principal value proposition of the offer, which may meet consumer needs with more material (e.g. products) or with immaterial components (e.g. services and experiences). Among the classifications proposed in the literature, three major PSS categories can be distinguished (Figure 2): product-oriented, use-oriented and result-oriented (Tukker, 2004).

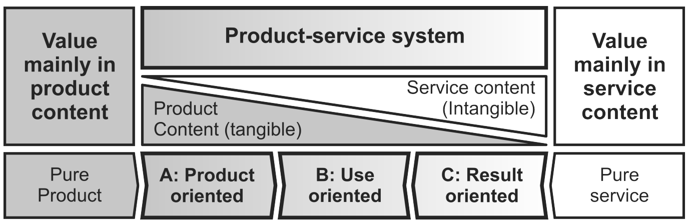

Figure 2: Main product-service system categories. Adapted from Tukker (2004).

In the product-oriented PSS, the business model is organised mainly around selling products. Usually, the end-user owns the product, and its functionality is offered for a given period with the support of services such as installation, maintenance and warranty. Additional services add value to the product and assist in lifecycle management. While product-oriented PSS is clearly focused on adding value to the product, its successful implementation will often require changes in infrastructure and user practice (Bartolomeo et al., 2003).

In the use-oriented PSS, on the other hand, while the product may still play a central role, the business model is not focused on selling product but on “sale of use”. In this case, the company is motivated to increase the efficiency of the product, and to extend the life of the materials used to produce it (Baines et al., 2007). In addition, because the product remains the property of the provider, the company can integrate additional services into the life cycle of the product, such as exchange, upgrade, reuse and disposal. This category of PSS seeks to make better use of under-utilised devices through such mechanisms as rental (where a provider hires out a product on a short-term basis but retains its ownership) and leasing (where a provider leases the use of a product on a long-term basis but retains its ownership) (Bartolomeo et al., 2003).

Finally, in a result-oriented PSS, the solution essentially involves applying the most suitable combination of products and services to meet the customer’s need. In this business model, the customer and the supplier agree in principle on a specific outcome, and for that reason, no predetermined product or technology is necessarily involved. The result-oriented PSS offers companies an opportunity to analyse the supply chain interacting with the service at all stages of the process. The aim is to establish partnerships enabling the construction of a network of stakeholders who are interested in working together in managing the products and services offered.

Materials and method

This paper introduces a master-level elective course called Product-Service Systems, which was delivered by the authors over a period of seven weeks in the academic year 2013–2014. The data reported here came from a set of PSS concepts targeting complex societal contexts as developed by student teams within the course. This education experiment was designed to apply knowledge and skills based on SOD theories, strategies, tools and other resources that might be useful in making design choices during product-service system development for complex societal problems.

Using a case study research methodology supported by protocol analysis, the sampled cases were for descriptive purposes rather than for inferential generalisation. The case study approach enabled comparison and comprehensive, detailed description of the students’ design activities. Each project was analysed as a unique case in order to characterise and highlight similarities and differences in how students used SOD to develop more sustainable solutions. This approach is particularly suitable for improving understanding of the problem and for theorising about new contexts (Berg, 2001).

Sample

The initial sample consisted of 12 multidisciplinary teams of 3–4 students from master programmes in Industrial Design Engineering, Industrial Ecology and Sustainable Energy Technology. At the beginning of the first workshop, all students completed a questionnaire on their educational background and their familiarity with complex societal contexts (i.e. humanitarian aid and low-income markets) and PSS design. To ensure that students had the same level of basic knowledge of the main study domains, there were two workshops with invited experts in the field of sustainable PSS design.

Course structure

The course focused on the development of new PSS concepts as an approach to sustainable innovation in complex societal contexts. Each class (workshop) comprised an introductory lecture, an explanation of one major phase of the PSS design process, an inspiring lecture by a professional with experience in the relevant domain, and finally, a hands-on exercise using one of the systems-oriented PSS tools. The design assignments were derived from real problems faced by two real clients: (I) to develop an innovative and sustainable lighting product-service system for Accord Illumination, a medium-sized enterprise in Brazil; and (II) to develop autoclave and cold-chain business model solutions for the innovation section of the international organization Medécins Sans Frontières (MSF) Sweden.

The course set five major student learning objectives: (I) to provide a broader knowledge base and skillset grounded in systems thinking; (II) to share basic knowledge of theory, concepts, approaches, methods and tools for Design for Sustainability, Sustainable System Innovation, PSS Design and Behaviour Change; (III) to provide insights into PSS implementation conditions, drivers and obstacles in practice, with particular reference to complex societal contexts; (IV) to provide knowledge and skills in the development and assessment of business models supporting successful introduction of the new PSS via existing businesses or new ventures; and (V) to develop understanding and design skills for multi-stakeholder environments.

The course resulted in twelve comprehensive PSS concepts, including six energy product-service systems (E-PSS) (assignment I) and six humanitarian product-service systems (H-PSS) (assignment II) (see Table 2).

Table 2: Overview of PSS concepts developed within the course.

No.	Project description	Assignment
1	Pay-per-use (card) LED light system	E-PSS
2	LED lighting products to empower local craftsmen	E-PSS
3	Self-sufficient solar LED leasing system enabling energy sharing	E-PSS
4	Local shop/school of modular LED light products to empower craftsmen	E-PSS
5	Lighting PSS based on local resources	E-PSS
6	Modular LED lighting kit for craftsmen	E-PSS
7	Sustainable leasing model of sterilisation equipment	H-PSS
8	Maintenance lab for medical devices	H-PSS
9	Digital sharing platform for cooling boxes	H-PSS
10	RFID monitoring system	H-PSS
11	Visual communication paper form to create awareness among cold chain drivers	H-PSS
12	Improved vaccine monitoring device	H-PSS

Source: Authors.

The PSS concepts were developed by the student teams under the authors' supervision, with regular interaction with the two clients.

Data analysis

Protocol analysis supported the analysis of design activities by capturing the influence of SOD on participants' cognitive skills and abilities. Protocol analysis is an observational research method, in which participants provide verbal accounts of their own cognitive activities. Previous empirical studies have successfully applied protocol analysis to gain insights into new approaches to design practice and education (Günther & Ehrlenspiel 1999; Adams et al. 2003). The data retrieved using protocol analysis served to illustrate how participants collected, generated and transformed context-specific information while developing solutions for the design assignments.

The PSS concepts were designed to take account of SOD-based training resources, including (I) sustainable PSS design processes and tools (Crul & Diehl, 2006; Halen, Vezzoli, & Wimmer, 2005; Vezzoli, 2010); (II) sustainable design strategies (Vezzoli, 2010); and (III) system design theory applied to design (Jones, 2014; Joore, 2010; Sevaldson, 2014). PSS concepts developed by the students were presented in the form of a report, visualisations and a final audio-visual presentation during an evaluation session with a jury panel composed of experts, scholars and the clients (n = 5). Concept evaluation employed the Sustainability Design-Orienting Toolkit (SDO toolkit) (Vezzoli & Tischner, 2005), which guides the design process towards sustainable solutions based on sustainability criteria along three main dimensions: environmental, socio-ethical and economic sustainability. The tool generates visualisations (i.e. radar diagrams) of potential environmental, socio-ethical and economic improvements that characterise the new product-service system (see Figure 3). Students were allowed to adapt the SDO toolkit criteria for their specific contexts as necessary.

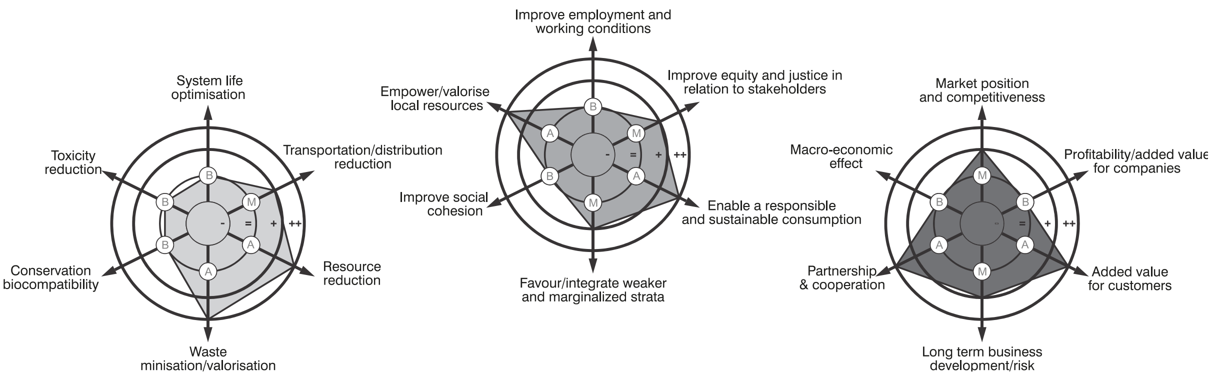

Figure 3: Example of a visualisation of SDO toolkit results (Vezzoli & Tischner, 2005).

Analysis of the concepts followed a systematic three-step procedure. First, student teams were asked to critically evaluate their own design by comparing their idea's radar diagram with the current target context situation. They then cross-compared each PSS idea generated. Second, the authors evaluated student concepts using the SDO toolkit checklist and the Student's Assignment Grading Tool. The complete data set was used in analysing how each of the student teams applied SOD, potential improvements resulting from the application of this approach, main advantages and, finally, any context- and process-related challenges.

The jury panel evaluation was carried out in the last session of the course during the final audio-visual presentations. The jury panel used a specific evaluation matrix focusing on the following areas: (I) context understanding; (II) PSS design process; (III) audio-visual presentation; and (IV) visualisations (e.g. poster, tools). Triangulation of these evaluations generated the overview presented in Tables 2 and 3, summarising the teams' attempts to promote potential environmental, socio-ethical and economic improvements in the PSS concepts.

Results

Systems-oriented design approach applied to product-service system concepts

This section describes the application of SOD in the development of the twelve PSS concepts. These included the concept of local shops providing energy-saving bulbs in Brazil for the company Accord Illumination, a sustainable leasing model of sterilisation equipment for MSF and a web-based monitoring platform for cooling boxes with vaccines. Figure 4 describes two student team projects in more detail.

E-PSS Concept 3—Light Energy: A sustainable product-service system for energy sharing

Light Energy aims to introduce a sustainable lighting system for Brazilian low-income households through a solar, LED rent-to-own system. This PSS enables end-users to save, produce and share their energy for lighting locally. Light Energy delivers a complete solution—an affordable, self-sufficient solar LED rent-to-own system for low-income households in the state of Paraná, in Brazil. The system will be offered by Light Energy, a cooperative based on the partnership between Accord, the local energy utility Copel and the housing company COHAPAR. In this collaboration, Accord's key contribution is their expertise in lighting systems and specifically in the new LED technology. Copel's key contribution is their expertise in all energy-related matters. To launch the system and its products successfully into the market, Light Energy will exploit COHAPAR's existing community network, which will be used as a communication channel between Light Energy and the end-user to raise awareness and ultimately to recruit and educate members of the community as "Accord ambassadors". These ambassadors will be key to building the Light Energy customer base by communicating the benefits of the new system directly to other members of the community. As part of the low-income community themselves, they can communicate the values and benefits of the new Light Energy PSS. This initiative allows people to experience the value of energy through the act of producing and sharing it within their personal network, supporting their relatives, friends and neighbours. The system enables users to engage in behavioural change for their own benefit. In addition, the PSS creates awareness of energy consumption and stimulates a new value perception that will make lower-income users more willing to pay for (legal) energy. The proposed solution includes options for multiple levels and types of subscription, matching PSS to the different needs and financial resources of members of the lower-income community. Additionally, where people improve their financial status over time, they can choose to upgrade their subscription.

H-PSS Concept 9—A digital sharing platform for cooling boxes

The Zazu system is an online platform that connects stakeholders in the humanitarian cold chain to each other and provides information about transported medicines through RFID technology in the cooling boxes. In the proposed PSS, new measuring devices that allow greater control of the cold chain process will replace the existing time-temperature monitoring devices. The solution includes a new cooling box design and an information system managed by humanitarian organisations and/or local governments. In the cooling box, medicines are kept cool by ice, as was the case in the original solution, because energy resources in remote areas cannot be relied on. Individual medicine packages have a passive RFID tag carrying information about the content of the package and its use. Information about medicine temperatures and locations is stored in the Zazu database and can be retrieved by stakeholders. The accessibility of these data allows organisations to make logistical decisions based on the condition of the medicines at a given moment (e.g. avoiding transport of medicines that have been exposed to excessive temperatures). The passive RFID tags do not rely on a power source, which makes them adaptable and suitable for large-scale implementation.

Figure 4: Two student team projects in detail.

Based on the data retrieved from the students' reports, visualisations and audio-visual presentations and from the hands-on workshops, we analysed the design choices made by each team. The analysis considered the attention given by students to each of the three dimensions of sustainability (i.e. socio-ethical, economic and environmental), revealing their priorities and struggles in approaching the complexity of the given problem. Three major trends were identified: (I) the need to adapt predefined criteria and strategies of the sustainability dimensions to better fit the needs of the context; (II) prioritising of one dimension over others; and (III) better understanding of the criteria and strategies of one dimension over others. The next section details these observations in terms of the specific dimensions of sustainability.

Need for context-specific information

During project development, the student teams expressed a need to introduce changes in the tools and strategies addressing the different dimensions of sustainability, especially with regard to the socio-ethical and economic dimensions (see Table 3). When applying PSS tools on these dimensions, the teams often created new criteria and strategies that were a better fit to the challenges their projects presented. For instance, in H-PSS concepts where there was the need to focus on more organisational issues, it was of paramount importance to specify social aspects around a specific user (e.g. communication and knowledge transfer, safety and usability) and economic aspects around organisations (e.g. scaling up business models and looking for R&D opportunities). Across the cases, it was observed that in order to overcome existing socio-ethical constraints and increase social benefits, the teams had to produce and rely heavily on context-specific information.

Prioritisation of sustainability dimensions

The analysis of PSS tools and final deliverables demonstrated that one particular dimension of sustainability tended to offer the most significant potential improvements. In the case of H-PSS concepts, the most significant improvement was achieved in the socio-ethical dimension; for E-PSS concepts, the economic dimension offered the most significant potential improvements. In some groups, E-PSS affordability was seen as the key to successful implementation of the project. For example, during idea generation, teams discussed a range of different payment systems such as pay-per-use, rent-to-own, leasing and supplementary electricity bill payment systems (e.g. exchanging discounts for services provided by users). Besides, some ideas involved product-service combinations to support income generation in low-income communities. Analysis of the PSS concepts indicated that in seeking to promote profound change, teams prioritised the dimension of sustainability considered essential in meeting the needs of the target socio-technical system.

Student background bias

The analysis established that teams achieved a better understanding of the criteria and strategies of the environmental dimension of sustainability, and all proved more assertive in applying the strategies and tools for this dimension. This was observed mainly in the report and visualisations, which presented a clearer and more complete description of environmental improvements as compared to other dimensions. We contend that these results are correlated with the design curriculum of the Master programmes at TU Delft, which offer multidisciplinary courses with particular emphasis on (environmental) sustainability.

Potential environmental, socio-ethical and economic improvements

To validate whether the potential improvements achieved by the PSS concepts could be traced back to the application of SOD, an in-depth analysis looked at how the teams applied the course content. This was done using a student assignment grading tool, which contained a step-by-step list of the theories, methods, strategies, and tools that students had to apply. The application of SOD resulted in potential environmental, socio-ethical and economic improvements in PSS concepts as compared to the current situation. Table 3 (next page) indicates the intention of student teams to promote environmental, socio-ethical and economic improvements in the development of PSS concepts. For instance, five out of six (5/6) student teams applied strategies for “Improving employment and working conditions” in developing their E-PSS and H-PSS concepts.

Based on project priorities, student teams created solutions for each criterion at different levels of intervention: “major improvement”, “incremental improvement”, “no significant change”, and finally, “worse”, when students opted to intentionally diminish the performance of a criterion. The teams were encouraged to customise, replace or even omit the SDO toolkit criteria to generate strategies that would better meet the needs of their specific context. Changes made by the teams to SDO criteria were not considered where the description of the new criterion was equivalent to the existent criterion (e.g. changing a criterion name but retaining the same strategy).

Table 3: Overview of strategies applied to promote environmental, socio-ethical and economic improvements in PSS concepts.

Sustainability Dimension	**SDO Criteria**	**PSS Concepts**	
		E-PSS	H-PSS
Social	Improving employment and working conditions	5/6	5/6
	Justice and equity on the part of stakeholders	3/6	1/6
	Enabling responsible, sustainable consumption	6/6	3/6
	Fostering and integrating the weak and marginalised	2/6	2/6
	Improvement of social cohesion	4/6	1/6
	Reinforcement/valorising of local resources	5/6	3/6
	* Knowledge transfer and communication between stakeholders	1/6	5/6
	* Awareness of effects on environment	1/6	0/6
	* Improving quality of life/living conditions	4/6	0/6
	* Health and safety	1/6	2/6
	* Social awareness and education	1/6	2/6
Economic	Market position and competitiveness	6/6	1/6
	Profitability/added value for businesses	5/6	2/6
	Added value for clients	5/6	5/6
	Long-term business development	6/6	5/6
	Partnership/cooperation	6/6	4/6
	Macroeconomic effect	4/6	2/6
	* Consumer lock-in	1/6	0/6
	* Quality perception by user of brand or product	0/6	2/6
	* Scalability/modularity to other organisations and sectors	0/6	2/6
	* Proactive search for R&D opportunities	0/6	1/6
	* Implementation/initiation/change costs	0/6	2/6
Environmental	System life optimisation	6/6	4/6
	Reduction in transport/distribution	4/6	3/6
	Reduction in resources	6/6	1/6
	Waste minimisation/valorisation of resources	5/6	5/6
	Conservation/biocompatibility	6/6	0/6
	Non-toxicity	3/6	0/6

SDO toolkit criteria formulated by the student teams. Source: Authors.

Discussion

The results reported in the previous section illuminate how SOD can support student teams in developing sustainable solutions for complex societal contexts. This section discusses the major advantages of using SOD as identified by this study and considers context- and process-related challenges. Finally, we discuss how future designers and engineers can be better prepared and equipped to deal with the problems faced in complex societal contexts.

Advantages of applying systems-oriented design

Based on an analysis of potential impacts of SOD, those potential impact factors were qualitatively categorised (using the SDO toolkit radar and each group's criteria) and clustered into groups of advantages. Table 4 summarises the identified advantages of SOD in developing solutions for complex societal contexts.

Table 4: Advantages of SOD when designing for complex societal contexts.

Sustainability Dimension	**Advantages**	**Example of application from evaluated concepts**
Social	- Think beyond the concept of affordability towards a concept of value creation. - Consider a broad network of stakeholders and their motivations for change as well as roles for new stakeholders from parallel industries. - Promote social integration and cohesion. - Empower the (local) end-user through education, employment and leadership. - Promote knowledge exchange and communication for improved awareness and consumption.	- E-PSS Concept 3 benefits from local ambassadors who connect and communicate with members of the community to convey the values and benefits of the new system. - H-PSS Concept 7 proposes a co-creation platform "from client to partner" that enables the continuous participation of different stakeholders through serious gaming facilitation. - H-PSS Concept 11 focuses on the acknowledgement and education of an often neglected but important stakeholder (local medicine transporters).
Economic	- Increase competitiveness and innovation. - Promote sharing of responsibilities and gains amongst stakeholders. - Consider positive macroeconomic impacts. - Design affordable solutions. - Offer added value for business. - Design scalable solutions with a long-term business perspective.	- E-PSS Concepts 6 and 3 use rent-to-own payment systems that allow ownership by paying the PSS over time. - H-PSS Concept 12 redesigns an existing solution, maintaining cost and focusing on increasing its value for organisations while optimising information and safety.
Environmental	- Consider technological and organisational dependencies of products. - Optimise lifecycle of products and services from manufacturing to disposal. - Valorise local material resources. - Reduce dependence on material resources and environmental footprint. - Promote awareness and choice of environmentally friendly resources.	- E-PSS Concept 1 promotes a pay-per-use system that encourages rational use of resources. - E-PSS Concept 4 uses a business model in which Accord provides product components and transfers knowledge to local branches to support them in running the business themselves. - H-PSS Concept 9 allows organisations to learn and to make logistical decisions through the cold chain monitoring process, which includes reducing the number of unnecessary trips. - H-PSS Concepts 9 and 10 emphasise the need to share and reuse devices.

Source: Authors.

Analysis of the case studies showed that a SOD approach could deliver impact to the different dimensions of sustainability. Table 4 illustrates several strategies repeatedly used by the teams to overcome project challenges. In particular, we observed that SOD stimulated student teams to embrace innovative approaches to decision-making about people, resources, economics, politics, markets, functions, needs and so on. SOD has been shown to be effective in increasing tolerance for uncertainty and encouraging a holistic approach to deal with complex problems (Cardenas et al., 2010).

The identified advantages confirm that student teams had to rely heavily on context-specific knowledge, so gaining a thorough understanding of the unique characteristics of those contexts. However, traditional product-service development knowledge offers methods, tools and strategies that isolate the components of the socio-technical system. For example, traditional product-service approaches produce changes along horizontal systems dynamics; individual changes such as product influence on users; organisational changes such as manufacturer influence on service providers; and societal changes such as policy instruments that influence social trends. In fact, the complex dynamics of complex societal contexts exert both "horizontal" and "vertical" influences on the construction of the socio-technical system (Figure 5) (Elzen et al., 2004).

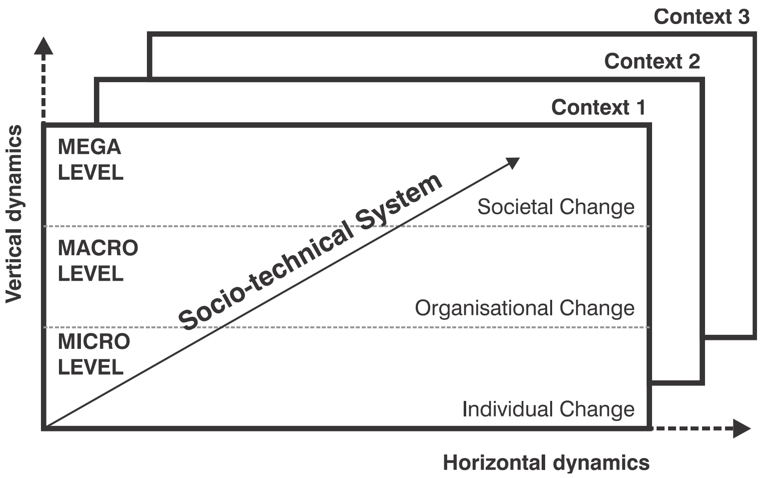

Figure 5: Dynamics of construction of a socio-technical system (based on Elzen et al., 2004).

As a mental model for understanding and framing problems while investigating solutions, SOD offered students a novel and broader perspective on both the vertical and horizontal dynamics of socio-technical systems. For example, the Stakeholders Motivation Matrix tool visualises multiple functional relations between stakeholders and explores the solution from the stakeholders' point-of-view by cross-referencing their motivations, interests and expectations (Morelli & Tollestrup, 2006). This tool enabled the teams to examine the influence of each stakeholder at different system levels simultaneously. In this way, the interrelations between stakeholders are preserved, decreasing potential conflicts and increasing synergy throughout the network of stakeholders.

Challenges of applying systems-oriented design

Along with the advantages, several challenges were identified in respect of context specificities and the PSS design process itself. These challenges are listed in Table 5 (next page). Although promising, application of SOD revealed a number of context- and process-related challenges. For example, student teams faced organisational barriers when presenting their ideas to the clients. Although the expansion of the stakeholders' network meant risk reduction for the organisation in most projects, the clients resisted opening up their operations and collaborating with new actors.

Table 5: Challenges of SOD approach when designing for challenging societal contexts.

	Challenges
Context-related	- Diversity of contexts at state or country level (e.g. government influence, infrastructure and education level) - Responsibility distribution among stakeholders in the long-term (e.g. international versus national) - Prioritisation/budget allocation due to dependency on donor or subsidy system - Poor diversity of available skills/expertise within the stakeholder network - Local end-user practices as coping mechanisms to overcome system difficulties
Process-related	- Communication within teams and with partners (e.g. mapping complexity versus structuring visualisations of systems) - Detailed information about context - Lack of organisational knowledge - Ideology-motivated decision making - Limitation to academic programs for project follow-up - Management of expectations about innovation outcomes (e.g. occasional feedback versus co-creation)

Towards a systems thinking approach in design engineering education

Based on the results of this study, the recommendations for design engineering educators set out below (Table 6) aim to achieve better results when applying SOD in educational settings.

Table 6: Recommendations for the use of SOD in educational settings.

Competency	Recommendation
Be aware	- Dependency on donor or economic instruments, such as subsidies and taxes, as a determinant of decision-making and priority setting - Diversity of local contexts, which are influenced by local norms, beliefs and circumstances (e.g. differences between local and regional context) - Poor diversity of available skills/expertise within the network of stakeholders - Ideologically motivated decision making
Ensure	- Engagement with the motivation of each stakeholder to assure their commitment to the project - Respect for local end-user practices
Communicate	- Hands-on process and visualisations to communicate complexity (e.g. system maps and GIGA-maps) - Involvement of maximum number of stakeholders in the process of creating visualisations to work as a shared mental model
Familiarise	- Stakeholders to be familiarised with the concept of PSS - Deficits in organisational knowledge addressed by developing preliminary strategic analysis or guaranteed access to vertical hierarchy of client
Manage	- Expectations regarding results, participation and shared responsibility.
Create an experimentation space	- Universities as spaces where knowledge is transferred and ideas are developed and tested - Support for follow-up projects within the University’s staff/courses/programmes

Role of the university: future directions at TU Delft

PSS has been formally taught at TU Delft and a range of other design engineering schools (e.g. Politecnico di Milano, Brunel University and Aalto University). However, few publications describe the effective conceptualisation and implementation of PSSs (see Diehl & Christiaans, 2015), especially in complex societal contexts. Also, few studies have considered PSS at system level (see Ceschin, 2012; Gaziulusoy, 2015; Santos, 2015). Although previous experiences of teaching PSS remain poorly reported in the literature, some authors have identified a number of reasons for shifting design education from product design and service design to PSS design (Cardenas et al., 2010; Diehl & Christiaans, 2015; Park & Benson, 2013).

In this study, the university played a central role as mediator in generating and transferring knowledge from context to stakeholders. In addition, the university provided a new knowledge base and expertise for students and clients in addressing the complexity of the assigned problems. Finally, the university prepared both organisations and students to embrace a different reasoning model. In this role, the authors as design researchers provided a knowledge base and skills based on SOD. However, this cannot replace the participation and openness of clients and other stakeholders. Designers are often keen to redefine a problem assignment and are usually triggered more by the problem-owner than by the information provided.

In PSS development, design engineers need to be equipped with appropriate methods, tools and strategies and must be prepared to engage with long-term development issues in multi-stakeholder environments (Diehl & Christiaans, 2015). This novel approach to complex societal problems requires new skills that are often overlooked in design engineering curricula. On the basis of this experience, preliminary guidelines for PSS application in complex societal contexts will continue to be developed in enhancing the future Product-Service System course at TU Delft.

Conclusion

Throughout this paper, we have emphasised that traditional product-service development knowledge may not be suitable for dealing with the large-scale wicked problems faced by contemporary society. The major drawbacks of traditional product-service development knowledge include limitations of rationale, lack of holistic approach and an inability to cope with complexity. Drawing on systems theory, design for sustainability strategies and PSS literature, we analysed the development of twelve PSS concepts designed by student teams on a multidisciplinary master course to demonstrate the applicability of SOD to PSS design. SOD offers design engineering students a broad knowledge base and skills for addressing design problems in complex societal contexts with the appropriate scope, depth and feasibility. The adoption of SOD in this education experiment served to identify the advantages and challenges of applying this approach in complex societal contexts such as low-income energy markets and humanitarian aid projects. In this process, the university played a crucial role in transferring knowledge between multiple stakeholders and fostering this novel approach in design engineering education.

Although the study achieved its aims, it has some limitations that affect the interpretation of the findings. Among those limitations, this educational experiment was conducted with a small sample comprising participants from a homogeneous background. In addition, the design assignments may contribute to bias due to its particular focus on energy and healthcare services. Despite confirming the promise of this approach in dealing with complex social contexts, further case studies are needed to assess the use of SOD in conjunction with traditional product-service approaches. Finally, this paper makes no attempt to propose specific tools for SOD, as an over-reliance on methods and tools may undermine the benefits of a systems-oriented approach (Ryan, 2014). Rather, we propose a radical shift in approach that will stimulate students to embrace complexity and assess the long-term feasibility of their solutions in addressing complex problems. For this radical shift to occur, and to progress these concepts, the future collaboration of problem-owners, governments, companies and non-governmental organisations is needed and welcomed.

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References

Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: the role of reflective practice. *Design Studies*, *24*(3), 275–294. doi:10.1016/S0142-694X(02)00056-X

Arnold, D. G., & Williams, L. H. D. (2012). The paradox at the base of the pyramid: environmental sustainability and market-based poverty alleviation. *International Journal of Technology Management*, *60*(1/2), 44. doi:10.1504/IJTM.2012.049105

Baines, T. S., Lightfoot, H. W., Evans, S. ., Neely, A. ., Greenough, R. ., Peppard, J. ., … Wilson, H. (2007). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10), 1543–1552. doi:10.1243/09544054JEM858

Bartolomeo, M., dal Maso, D., de Jong, P., Eder, P., Groenewegen, P., Hopkinson, P., … 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*(8), 829–837. doi:10.1016/S0959-6526(02)00157-9

Berg, B. L. (2001). *Qualitative research methods for the social sciences*. *Qualitative Research* (7th ed.). Long Beach: California State University.

Betts, A., & Bloom, L. (2014). *Humanitarian Innovation: The state of the art*. *OCHA policy and studies series* (Vol. 9). New York, NY: United Nations Office for the Coordination of Humanitarian Affairs (OCHA).

Binder, A., & Witte, J. M. (2007). *Business engagement in humanitarian relief: key trends and policy implications*. *An HPG Background Paper*. London.

Boeijen, A. Van, & Stappers, P. (2011a). Preparing Western designers for the use of contextmapping techniques in non-Western situations. In *Proceedings Engineering and Product Design Education conference* (pp. 1–6).

Boeijen, A. Van, & Stappers, P. J. (2011b). Serving the Underserved: What Can Designers Learn From Rural Appraisal Techniques? In *Proceedings of IASDR2011* (pp. 1–9). Delft, The Netherlands.

Brezet, H. (1997). Dynamics in ecodesign practice. *Industry and Environment*, *20*(1-2), 21–24.

Cardenas, C., Sosa, R., Moysen, R., & Martinez, V. (2010). Sustaining Sustainable Design through Systemic Thinking. *International Journal of Engineering Education*, *26*(2), 287–292.

Ceschin, F. (2012). *The introduction and scaling up of sustainable Product-Service Systems: A new role for strategic design for sustainability*. Politecnico di Milano.

Chavan, A. L., Gorney, D., Prabhu, B., & Arora, S. (2009). The washing machine that ate my sari—mistakes in cross-cultural design. *Interactions*, *16*(1), 26. doi:10.1145/1456202.1456209

Cozzens, S. E. (2012). Social cohesion at the global level: The roles of science and technology. *Science and Public Policy*, *39*(5), 557–561. doi:10.1093/scipol/scs067

Crul, M. M. R., & Diehl, J. C. (2006). Design for Sustainability. A Practical Approach for Developing Economies. UNEP/Earthprint.

Diehl, J. C., & Christiaans, H. H. C. M. (2015). Sustainble Product Service Systems: The future for designers? In *Proceedings of the International Design Congress*. Gwangju.

Elzen, B., Geels, F. W., & Green, K. (2004). System Innovation and the Transition to Sustainability: Theory, Evidence and Policy. Cheltenham, UK: Edward Elgar Publishing. doi:10.4337/9781845423421

Francois, P. (2002). *Social Capital and Economic Development*. Taylor & Francis.

Gaziulusoy, A. I. (2015). A critical review of approaches available for design and innovation teams through the perspective of sustainability science and system innovation theories. *Journal of Cleaner Production*, *51*, 744–751. doi:10.1016/j.jclepro.2015.01.012

Gaziulusoy, A. I., Boyle, C., & McDowall, R. (2011). System Innovation for Sustainability at Product Development Level: A Scenario Method and a Workshop Process. In *Proceedings of the Tao of Sustainability: An International Conference on Sustainable Design Strategies in a Globalization Context*. Beijing, China.

Geels, F. (2005). *Technological transitions and system innovations: a co-evolutionary and socio-technical analysis*. Cheltenham, UK: Edward Elgar Publishing.

Gershenson, C., & Heylighen, F. (2004). How can we think the complex? In K. Richardson (Ed.), *Managing the Complex Vol.1: Philosophy, Theory and Application* (pp. 47–62). Greenwich: Information Age Publishing.

Günther, J., & Ehrlenspiel, K. (1999). Comparing designers from practice and designers with systematic design education. *Design Studies*, *20*(5), 439–451. doi:10.1016/S0142-694X(99)00019-8

Halen, C. van, Vezzoli, C., & Wimmer, R. (2005). *Methodology for Product Service System Innovation: How to implement clean, clever and competitive strategies in European industries*. Assen, Netherlands: Royal Van Gorcum.

Hanna, R., Duflo, E., & Greenstone, M. (2012). Up in Smoke : The Influence of Household Behavior on the Long-Run Impact of Improved Cooking Stoves (No. w18033). National Bureau of Economic Research.

Hart, S. L., & Sharma, S. (2004). Engaging fringe stakeholders for competitive imagination. *The Academy of Management Executive*, *18*(1), 7–18. doi:10.5465/AME.2004.12691227

Jones, P. H. (2014). Systemic Design Principles for Complex Social Systems. In G. S. Metcalf (Ed.), *Social Systems and Design* (Vol. 1, pp. 91–128). Tokyo: Springer Japan. doi:10.1007/978-4-431-54478-4

Joore, P. (2008). The V-Cycle for system innovation translating a broad societal need into concrete product service solutions: the multifunctional centre Apeldoorn case. *Journal of Cleaner Production*, *16*(11), 1153–1162. doi:10.1016/j.jclepro.2007.08.007

Joore, P. (2010). *New to Improve—The Mutual Influence between New Products and Societal Change Processes*. JP Joore.

London, T., & Hart, S. L. (2004). Reinventing strategies for emerging markets: beyond the transnational model. *Journal of International Business Studies*, *35*(5), 350–370.

Mahajan, V., & Banga, K. (2005). *The 86 Percent Solution: How to Succeed in the Biggest Market Opportunity of the Next 50 Years*. New Jersey: Prentice Hall.

Manzini, E., & 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*(8), 851–857. doi:10.1016/S0959-6526(02)00153-1

Margolin, V. (1995). The Politics of the Artificial. *Leonardo*, *28*(5), 349. doi:10.2307/1576217

Matos, S., & Silvestre, B. S. (2012). Managing stakeholder relations when developing sustainable business models: the case of the Brazilian energy sector. *Journal of Cleaner Production, 45,* 61–73. doi:10.1016/j.jclepro.2012.04.023

Mays, R. E., Racadio, R., & Gugerty, M. K. (2012). Competing constraints: The operational mismatch between business logistics and humanitarian effectiveness. *Proceedings—2012 IEEE Global Humanitarian Technology Conference, GHTC 2012*. doi:10.1109/GHTC.2012.29

Mont, O. (2002a). Clarifying the concept of product-service system. *Journal of Cleaner Production*, *10*(3), 237–245. doi:http://dx.doi.org/10.1016/S0959-6526(01)00039-7

Mont, O. (2002b). Drivers and barriers for shifting towards more service-oriented businesses: Analysis of the PSS field and contributions from Sweden. *Journal of Sustainable Product Design*, *2*(3/4), 89–103. doi:10.1023/B:JSPD.0000031027.49545.2b

Morelli, N., & Tollestrup, C. (2006). New representation techniques for desigining in a systemic perspective. In *Proceedings of the Engineering and Product Design Education Conference*. Salzburg University of Applied Sciences, Salzburg.

Nelson, H. G. (2007). Simply Complex by Design. *Performance Improvement Quarterly*, *20*(2), 97–115. doi:10.1111/j.1937-8327.2007.tb00443.x

Nielsen, B., & Santos, A. L. R. (2013). Key challenges of product development for humanitarian markets. In *2013 IEEE Global Humanitarian Technology Conference (GHTC)*. doi:10.1109/GHTC.2013.6713721

Park, H., & Benson, E. (2013). Systems thinking and connecting the silos of design education. In *Proceedings of International Conference on Engineering and Product Design Education*.

Penin, L. (2006). *Strategic design for social sustainability in emerging contexts*. Politecnico di Milano.

Prahalad, C. K., & Ramaswamy, V. (2004). Co-creation experiences: The next practice in value creation. *Journal of Interactive Marketing*, *18*(3), 5–14. doi:10.1002/dir.20015

Raduma, W. (2011). Occupy Reimagining Design. *The ReReThinking Series*.

Ramalingam, B., Scriven, K., & Foley, C. (2009). Innovations in international humanitarian action. In *8th Review of Humanitarian Actions: Perfomance, Impact and Innovation* (pp. 1–88), ALNAP.

Reinders, A., Diehl, J. C., & Brezet, H. (2012). *The Power of Design: Product Innovation in Sustainable Energy Technologies*. Wiley.

Rocchi, S. (2005). *Enhancing Sustainable Innovation by Design: An Approach to the Co-creation of Economic, Social and Environmental Value.* Erasmus University Rotterdam.

Ryan, A. J. (2014). A Framework for Systemic Design. *FORMakademisk*, *7*(4), 1–14.

Santos, A. L. R. (2015). *Mind the gap: Designing Sustainable Healthcare for Humanitarian Aid.* (Doctoral dissertation). TU Delft, Delft University of Technology.

Santos, A. L. R., & Wauben, L. S. G. L. (2014). Systems Design Perspective of Healthcare Provision in Humanitarian Aid. *FORMakademisk*, *7*(3), 1–19.

Schäfer, M., Jaeger-Erben, M., & Santos, A. (2011). Leapfrogging to Sustainable Consumption? An Explorative Survey of Consumption Habits and Orientations in Southern Brazil. *Journal of Consumer Policy*, *34*(1), 175–196. doi:10.1007/s10603-010-9150-5

Sevaldson, B. (2008). A system approach to design learning. In A. Menges (Ed.), *Systemisches Denken Und Integrales Entwerfen / System Thinking and Integral Design*. Offenbach: Hochschulverlag HFG.

Sevaldson, B. (2009). Why should we and how can we make the design process more complex ? In *Shaping Futures* (pp. 274–281). Oslo: IDE.

Sevaldson, B. (2010). Discussions & Movements in Design Research: A systems approach to practice research in design. *FORMakademisk*, *3*(1), 8–35.

Sevaldson, B. (2011). Giga-mapping: Visualisation for complexity and systems thinking in design. In *Nordes '11: The 4th Nordic Design Research Conference*, pp. 137–156.

Sevaldson, B. (2013). Systems Oriented Design: The emergence and development of a designerly approach to address complexity. In *2nd International Conference for Design Education Researchers*. Oslo, Norway.

Sevaldson, B. (2014). System Oriented Design. Retrieved from http://www.systemsorienteddesign.net/

Sevaldson, B., Hensel, M. U., & Frostell, B. (2010). Systems-oriented design and sustainability. Proceedings of the Learning Network on Sustainability (LeNS) conference: *Sustainability in Design—Now! Challenges and Opportunities for Design Research, Education and Practice in the XXI Century*, (x), 29 Sep–01 Oct, Bangalore, India.

Tatham, P., & Houghton, L. (2011). The wicked problem of humanitarian logistics and disaster relief aid. *Journal of Humanitarian Logistics and Supply Chain Management*, *1*(1), 15–31. doi:10.1108/20426741111122394

Tischner, U. (2006). Sustainable and Humanitarian Design Education. In E. S. Sotamaa & L. Anusionwu (Eds.), *Nantes: Cumulus Working Papers*. Helsinki: University of Art and Design Helsinki.

Tischner, U., & Verkuijl, M. (2006). Design for (Social) Sustainability and Radical Change. In *Perspectives on Radical Changes to Sustain- able Consumption and Production* (pp. 199–215). Copenhagen.

UNEP. (2001). *The Role Of Product Service Systems in a Sustainable Society*. Paris.

UNEP. (2002). *Product-Service Systems and Sustainability: Opportunities for sustainable solutions*. Paris.

Vanpatter, G. K., & Jones, P. (2009). Design 1.0, 2.0, 3.0, 4.0; The Rise of Visual SenseMaking. *NextD Journal*, (March), 1–12.

Vasantha, G. V. A., Roy, R., Lelah, A., & Brissaud, D. (2012). A review of product-service systems design methodologies. *Journal of Engineering Design*, *23*(9), 635–659. doi:10.1080/09544828.2011.639712

Vezzoli, C. (2010). *System Design for Sustainability: Theory, Methods and Tools for a Sustainable "satisfaction-system" Design*. Milan: Maggioli Editore.

Vezzoli, C., Ceschin, F., & Kemp, R. (2008). Designing transition paths for the diffusion of sustainable system innovations. A new potential role for design in transition management? In *Changing the change. Design, visions, proposals and tools*, 10–12 July, Turin, Italy.

Vezzoli, C., Kohtala, C., Srinivasan, A., Diehl, J. C., Fusakul, S. M., Xin, L., & Sateesh, D. (2014). *Product-Service System Design for Sustainability*. Greenleaf Publishing. doi:http://dx.doi.org/10.9774/GLEAF.978-1-909493-69-8_8

Vezzoli, C., & Tischner, U. (2005). Sustainability design-orienting toolkit (SDO-MEPSS). Retrieved from http://www.mepss-sdo.polimi.it/mepss/website/mepss.html

Viswanathan, M., & Rosa, J. (2007). Product and market development for subsistence marketplaces: consumption and entrepreneurship beyond literacy and resource barriers. *Advances in International Management*, *20*(1), 1–17. doi:10.1016/S1571-5027(07)20001-4

Viswanathan, M., & Sridharan, S. (2012). Product Development for the BoP: Insights on Concept and Prototype Development from University-Based Student Projects in India. *Journal of Product Innovation Management*, *29*(1), 52–69. doi:10.1111/j.1540-5885.2011.00878.x

Webb, J. W., Kistruck, G. M., Ireland, R. D., & Ketchen, Jr., D. J. (2010). The Entrepreneurship Process in Base of the Pyramid Markets: The Case of Multinational Enterprise/Nongovernment Organization Alliances. *Entrepreneurship Theory and Practice*, *34*(3), 555–581. doi:10.1111/j.1540-6520.2009.00349.x