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Introduction

Humanitarian organizations and governments face a particular challenge when providing services, such as energy and healthcare to contexts with poor financial and infrastructural resources. These complex and challenging societal contexts call for alternatives to traditional business. In order to succeed, these stakeholders need to adopt several unconventional tasks like product distribution and servicing which, in most cases, customers or end-users are not capable of affording [1]. In addition, in such a resource-limited societal contexts, the complexity and ambiguity between the interests within the network of stakeholders is higher than in traditional businesses [2]. Furthermore, the end-user is mostly considered as a passive recipient, dependent on own coping mechanisms to benefit from the provided services.

When addressing complex societal problems, Systemic Design has been recognized in literature as a solution likely to achieve better and more sustainable results than a traditional product design approach [3], [4]. Systemic Design considers different system hierarchies within a particular socio-technical system. A socio-technical system is a number of clustered elements, such as technology, policies, user practices, markets, culture and infrastructure, which are linked together to attain a specific functionality in a system [5]. By broadening the scope and complexity of design practice, Systems Design increases the capacity of the (socio-technical) system to address its function [6]. Systems Design understands that solely (re)designing products to be affordable is not enough to guarantee their adoption and thus render the function of the system to be comprehensively accomplished [7], [8]. As such, it proposes the design of a coherent combination of processes and products that together fulfil the function of the system.

For designers this means handling a larger degree of complexity and making a more sustainable changes by considering value creation through a long-term timeframe and the involvement of a larger network of stakeholders [3], [9]. Therefore, relying on existing product development knowledge (i.e. methods, tools and techniques) restricts the design process creating an inability to understand the local context [10]. Using Systemic Design encourages designers to consider aspects beyond technology, related to business, lifecycle and stakeholders motivations [11], [12]. Because designers and researchers are typically educated to apply traditional product development, in this novel innovation network, universities increasingly gain relevance as essential partners for system change [13].

The current study builds upon Santos (2014), where a systemic design approach was proposed to address complex problems in challenging societal contexts. It aims to describe the process of using Universities as a base for knowledge transfer between multiple stakeholders when addressing, in emerging economies, the need for affordable energy in low-income households and humanitarian aid of sterilization and of cold chain monitoring. The study was carried out during an elective course called Product-Service Systems from the Industrial Design Engineering Master Programme provided by the Faculty of Industrial Design Engineering at Delft University of Technology (TU Delft). It took place in collaboration with the Federal University of Paraná (and partners) in Brazil, and the innovation section of the international organization Medécins Sans Frontières in Sweden. The paper is structured as follows. In the next section is presented a literature review of characteristics of complex societal contexts, systemic design and PSSs design. In the subsequent sections, the research method adopted and a summary of the projects developed is presented. Finally, based upon the previous sections, the findings are presented and discussed. We conclude with implications for future studies.

Materials and Method

The data used in this study came from a set of product-service systems (PSS) concepts targeted for complex societal contexts, conducted by student teams in a multidisciplinary master course. The course, called Product-Service System, consisted in a seven weeks workshop conducted by the authors in the Industrial Design Engineering Master Programme at Delft University of Technology (TU Delft) in 2014. In the first workshop of the course, all students filled in a questionnaire on their educational background and familiarity with complex societal contexts (i.e. humanitarian relief, low-income contexts) and product-service system design. In order to ensure that students had the same level of basic knowledge on the main domains this study, in each workshop they are trained by the authors and invited sustainable design experts. Each class comprised an introductory lecture, a major phase of PSS process, an inspiring lecture by a sustainable design experts and a hands-on practice of a relevant PSS tool.

The student body were composed by multidisciplinary teams of 3-4 students, with background from industrial design and industrial ecology disciplines, working on a sustainable product-service system assignment. The design assignment was derived from real problems faced by two real clients, (i) the medium-sized enterprise Accord Illumination in Brazil, and (ii) the innovation section of the international organization Medécins Sans Frontières in Sweden. The course resulted in 12 comprehensive concepts, which were developed and monitored in accordance with the clients assignments.

In this study, each student project is analysed as a unique case study. The sample of cases is meant for descriptive and not inferential generalisation. It includes six energy product-service systems (E-PSS) and six humanitarian product-service systems (H-PSS). Therefore, the multiple case studies approach adopted is comparative, proposing to understand and explain similarities and differences (i.e. unique or contrasting aspects) across the cases. This approach is particularly suitable to better understand the nature of the problem and to theorize about new contexts [14].

Data analysis

Students created PSS concepts taking into consideration PSS processes and tools [15]–[17], sustainable design strategies [17] and system design theory [3], [18]. The resulted PSS concepts were

presented by means of a report, visualizations and a final audio-visual presentation. The outcome was presented to their peers and a jury member composed by experts, scholars and the clients. The concept evaluation was carried out using the tool Sustainability Design-Orienting Toolkit (SDO). SDO aims to orientate the design process towards sustainable PSS solutions based on sustainability criteria on three main dimensions: environmental sustainability, socio-ethical sustainability and economic sustainability. The tool results in visualizations (i.e. radar diagram) of the potential environmental, socio-ethical and economic improvements that characterise the new product service system (see figure 1). Students were allowed to adapt the SDO criteria with their specific contexts when necessary.

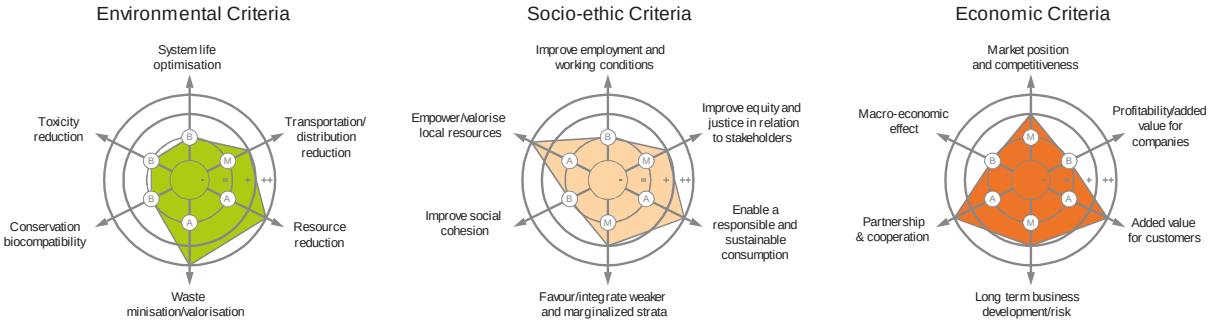

Fig. 1. Example of a visualization of the results of the SDO. Source: [17].

The analysis of the concepts followed a three-step procedure. First, students teams were asked to critically evaluate their designs by comparing the SDO criteria with the current situation of the contexts, as well between the PSS ideas generated. Second, an evaluation of the students concepts were conducted by the authors using the SDO. Finally, an evaluation took place by a panel of sustainable design experts (i.e. experts and scholars of the jury). The next section describes the preliminary findings of the analysis.

Results: Advantages and challenges of systems design

As mentioned before, the course resulted in 12 comprehensive concepts: six energy product-service systems (E-PSS) and six humanitarian product-service systems (H-PSS) (see Table 1). These include, for instance, a concept of entrepreneur local shops of energy saving bulbs in Brazil for the company Accord Illumination, a sustainable leasing model of sterilization equipment for Medécins Sans Frontières and a web-based monitoring platform for cooling boxes with vaccines.

Table 1
Overview of the resulted PSS concepts of the course

No.	Project description	Assignment
1	Pay-per-use (card) LED light system	Energy PSS
2	LED lighting products that empower local craftsmen	Energy PSS
3	Self sufficient solar LED leasing system that enables energy sharing	Energy PSS
4	Local shop/school of modular LED-light products that empower craftsmen	Energy PSS
5	Lighting PSS based on local resources	Energy PSS
6	Modular LED lighting kit for craftsmen	Energy PSS
7	Sustainable leasing model of sterilization equipment	Humanitarian PSS

8	Maintenance lab for medical devices	Humanitarian PSS
9	A digital sharing platform for cooling boxes	Humanitarian PSS
10	RFID monitoring system	Humanitarian PSS
11	Visual communication paper form to create awareness amongst cold chain drivers	Humanitarian PSS
12	Improved vaccine monitoring device	Humanitarian PSS

In order to illustrate the preliminary results, Table 2 shows an overview of the potential environmental, socio-ethical and economic improvements of the Energy PSS concepts, based on the triangulation of the evaluation of the students projects.

Table 2
Potential environmental, socio-ethical and economic improvements of the PSS concepts.

	SDO Criteria	**Project**					
		1	**2**	**3**	**4**	**5**	**6**
Social	Improve employment and working conditions	++	++	+	=	++	++
	Justice and equity on the part of stakeholders	+	++	++	+	+	*
	Enabling of responsible, sustainable consumption	++	++	++	++	+	+
	Fostering and integration of the weak and marginalised	+	++	*	*	*	*
	Improvement of social cohesion	++	++	++	+	*	+
	Reinforcement/valorising of local resources	++	++	=	+	++	+
Economic	Market position and competitiveness	+	++	+	++	++	+
	Profitability/added value for businesses	++	++	+	=	*	+
	Added value for clients	++	++	++	++	*	++
	Long-term business development	++	++	++	++	++	++
	Partnership/cooperation	++	++	+	=	+	++
	Macro-economic effect	++	++	+	=	+	+
Environmental	System life optimisation	++	++	+	+	++	++
	Reduction in transport/distribution	++	++	=	+	*	+
	Reduction in resources	++	++	+	+	+	++
	Waste minimisation/valorisation of resources	++	++	=	++	++	+
	Conservation/biocompatibility	++	++	+	++	+	++
	Non-toxicity	++	++	=	=	*	+

Based on the project priorities, for each criterion, students created solutions with different levels of improvement: radical improvement (++), incremental improvement (+), no significant change (=), worse (-), and finally, for custom or omitted criteria (*)[1]. Built upon all 12 students projects, Table 3 shows the preliminary advantages of using a Systems Design approach to design solutions for challenging societal contexts.

Table 3
Advantages of a Systems Design approach when designing for challenging societal contexts

[1] An additional table with customized criteria will be presented in the final paper.

	Advantages
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 for 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;
Economic	- Increase competitiveness and innovation; - Promote sharing of responsibilities and gains amongst stakeholders; - Consider positive macroeconomic impact; - Design of affordable solutions; - Offer added value for business; - Design of scalable solutions with a long-term business perspective;
Environmental	- Consider technological and organizational dependencies of products; - Optimize lifecycle of products and services - from manufacturing to disposal; - Valorise local material resources; - Reduce dependency on material resources and environmental footprint; - Promote awareness and choice of environmentally-friendly resources;

In parallel to these advantages, several challenges were identified regarding context specificities and the design process itself. These challenges are listed in Table 4.

Table 4
Challenges of a Systems Design 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 amongst stakeholders on the long-term (e.g. international *versus* national); - Determining prioritization/budget allocation due to dependency on donor or subsidy system; - Poor diversity of available skills/expertise within the stakeholder network; - Local end-user practices that result as coping mechanisms to overcome system difficulties.
Process-related	- Communication within teams and with partners (e.g. mapping complexity *versus* structuring visualizations of systems); - Detailed information about context; - Lack of organizational 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).

In summary, the preliminary results show that there are advantages and challenges when applying a Systems Design approach for challenging societal contexts. One essential key for the success of the

Systems Design approach is the end-user and context related knowledge. However, the available knowledge for designers is not systematic. Throughout this course, the role of university was key as a mediator to generate and transfer knowledge of the context to the involved stakeholders. On basis of this experience, preliminary guidelines for PSS application in challenging societal contexts will continue to be developed as an improvement for the future PSS course at TU Delft. Further studies (i.e. building systemic design capabilities in designers) will be carried out and the complete results will be included in the final paper.

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