



WHY CHOOSE ONE SUSTAINABLE DESIGN STRATEGY OVER ANOTHER: A DECISION-SUPPORT PROTOTYPE

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Abstract

Sustainable design strategies provide tangible ways for integrating sustainability into early phase product design work. Examples include design for remanufacturing and design for the base of the pyramid. There are many such strategies and it is difficult to choose between them. Sustainable product design activities also need to be tailored to business priorities. We therefore designed a decision-support prototype to aid project teams to choose strategies based on relevance to the project in terms of both business and sustainability value. To design the prototype, we first identified potential strategies from sustainable product development literature. We then used literature on each of six selected strategies to identify potential business and sustainability benefits. We developed a way to compare sustainability value based on a scientifically established definition of sustainability and a lifecycle perspective. The prototype is designed to be usable by practitioners who are not necessarily sustainable design experts. The prototype was created to enable future work to test ways to integrate the selection of sustainable design strategies into the early phases of product design.

Keywords: Sustainability, Ecodesign, Circular economy, Design for X (DfX), Sustainable design

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1 INTRODUCTION

In this study, we designed a decision-support prototype to aid project teams to select which sustainable product design strategies to employ in a given product development project. Sustainable design strategies direct early phase design work to contribute to society's transition to sustainability, with each strategy doing so from a slightly different perspective. Example strategies include design for remanufacture and design for the base of the pyramid. A high number of such strategies exist and it is difficult to select the most appropriate one(s) (Rossi et al., 2016).

By providing direction, sustainable design strategies enable integration of sustainability thinking into idea generating processes and practices. Integrating sustainability into product design, rather than developing stand-alone sustainability tools and methods, is critical (Baumann et al., 2002; Brones and de Carvalho, 2015). Even the international standard ISO14006:2011, describes sustainable product design as involving *integrating* sustainability¹ aspects into product design. Furthermore, support for integrating sustainability aspects into decision-making should vary with the type of activity (Arvai et al., 2012); not just focusing on analysis activities as is common. Sustainable design strategies are therefore worthwhile considering since they enable both integration and the ability to support ideation. Through choosing strategies that are relevant to a particular project, project teams can work with sustainability in a way that also delivers business benefits. In other words, it enables companies to work strategically with sustainable product design, which is in line with strategic sustainable development as described by Broman and Robert (2017). According to European ecodesign practitioners, it is a problem that current sustainable product design support often lacks the ability to tailor sustainable product design work to business needs (Prendeville et al., 2013). In addition, from a pure decision-making perspective, emphasizing values and value-trade-offs helps decision-makers to navigate the complexity of the context and focus on what matters for the given project (Arvai et al., 2001; Keeney, 1992).

The relevance of a sustainable design strategy to a project depends not only on potential business value, but different projects also have different sustainable design opportunities. For example, designing electrical equipment (with slower innovation cycles, common materials, and well-known use scenarios) is a very different context with different possibilities for sustainable design than designing electronic equipment (with shorter innovation time, specialised materials and evolving usage) (Unger et al., 2008). Combining business and sustainability considerations is in line with needs and trends in the sustainable product design research field. Baumann et al. (2002) stated that the lack of progress from trial use of sustainable product design support to systematic use may be due to lack of consideration of the broader business system. However, the research field has since developed and is shifting from trying to propose theoretically correct, detailed and exhaustive support to proposing strategies that consider the opportunities and limitations of the business world (Rossi et al., 2016) and have a more explicit focus on the strategic implementation of sustainable product design (Pigosso et al., 2016).

The objective of our study was *to design a prototype that provides information on the business and sustainability value² of various sustainable product design strategies in order to help project teams to select which strategy/ies they will employ in a given project*. Bovea and Pérez-Belis (2012) and Byggeth and Hochschorner (2006) have done this with environmental requirements and evaluation tools, whereas we are doing it with design strategies. This objective entails analysing the strategies in order to provide information that supports value-based decision-making. When facing trade-off decisions, and particularly when integrating sustainability aspects, analysis should be performed by specialists and be fact-based whereas judgements should be made by decision-makers and be value-based (Gregory et al., 2012). The purpose of designing a decision-support prototype is to enable prototyping of a general approach of selecting and using design strategies in design-thinking and stage-gate product development processes. In line with Kelley (2001), prototyping should help us to learn quickly and early, before investing in more detailed development. The prototype will therefore not exhaustively cover all design strategies, but provide a first version that can be used in further research.

¹ The ISO describes only environmental aspects whereas we use a definition of sustainability that also includes social aspects. This is in line with the framework for strategic sustainable development (Broman and Robert, 2017) and the transition in the product design field towards a more holistic view (Boks and McAloone, 2009).

² Definition of value (Cambridge online English dictionary): "how useful or important something is".

2 RESEARCH APPROACH

The research approach was an iteration between the three phases outlined below.

2.1 Phase 1: Identifying sustainable design strategies

The first phase involved identifying the strategies to be included in the prototype. Our aim was a set of representative strategies that together provide at least the minimum to help us learn 'quickly and early'. In order to choose strategies that are representative, we used existing literature to identify sustainable design strategies. To find peer reviewed literature that provides an overview or list of strategies, we searched with our institution's Summon service (to search all databases to which the institution subscribes) with the following search terms: sustainable design, ecodesign, eco-design, ecodesign review, eco-design review, design for x, sustainable product development, sustainable product design, design for sustainability, and sustainable design strategies product. Papers covering just one strategy were not included in this phase, only articles reviewing or listing multiple sustainable product design strategies were included.

Through reading titles (of 835 papers) and prioritising journal articles, we down-selected to reading 150 abstracts. Further reading and snowballing resulted in 113 papers, including 84 from journals. From this literature we obtained lists of strategies and chose 6 strategies to include in the prototype; see section 3.

2.2 Phase 2: Understanding sustainability & business value of a number of strategies

We individually collected, handled, analysed and interpreted data on the strategies before then discussing and iterating the interpretation as a team. We collected data from existing literature, prioritising review and journal articles over conference articles and books. The aim was to include multiple authors and negative cases in order increase quality. Records were kept of which articles were read. We sought to use the literature to understand the potential value (business and sustainability) of implementing each specific strategy and the conditions under which that value might be delivered.

In order to analyse for potential sustainability value, we took a lifecycle perspective and used the following definition of sustainability (known as sustainability principles): In a sustainable society, nature is not subject to systematically increasing... 1. ...concentrations of substances extracted from the Earth's crust; 2. ...concentrations of substances produced by society; 3. ...degradation by physical means; and people are not subject to structural obstacles to... 4. ...health; 5. ...influence; 6. ...competence; 7. ...impartiality; 8. ...meaning-making (Broman and Robert, 2017). In line with modern work on sustainable product design including both social and ecological aspects of sustainability (Boks and McAloone, 2009), we wanted a definition that includes both. We also chose this definition due to its strong scientific basis. Specifically, we used the literature to identify how each strategy might contribute to society's transition towards sustainability, as defined by the above principles, in different parts of the lifecycle. We iterated through discussion among the authors in weekly workshops over three months.

2.3 Phase 3: Presenting the information in a decision-support prototype

In order to design a prototype, we needed to understand how to present the gathered information in order to support good decision-making. See section 4 for what we found in the literature.

2.4 Methodological quality considerations

We acknowledge that we have an inclination to view the sustainable design strategies in a positive light - to expect to find business-sustainability win-wins. To help avoid confirmation bias, we sought to find failure cases and arguments (in line with Oswald and Grosjean (2004)). We also used the following approaches for quality qualitative research from Savin-Baden and Howell Major (2013): (i) Triangulation of data: multiple papers from multiple authors. (ii) Triangulation of researchers: at least three researchers discussed and iterated the analysis of each strategy and performed the interpretation across strategies. (iii) Audit trail: we kept records of which documents have been read and justifications for analysis. (iv) Negative case analysis: as mentioned, we sought to find negative cases.

3 RESULTS: WHICH STRATEGIES TO INCLUDE?

We identified the following strategies and sub-strategies from the listed literature.

- Strategies: Design for the base of the pyramid (1), Design for social innovation (1), Design for behaviour change for sustainability (1), Product-service system design for sustainability /Design for service /Functional optimisation /Shared use of product (1,2,3), Design for life extension /long life (2,3,4), Design for re-use (2,3), Design for remanufacture /repair & upgrade /easier maintenance & repair /repair & maintenance (3,4,5,6), Design for recycling (1,2,3,5), Design for energy recovery /safer incineration (2,3), Design for disposability (2), Design for energy efficiency (1,3,4,5), *Design for closing the loop /recovery /circular supply chain /Optimise end-of-life /Cradle-to-cradle (1,3,5).
- Sub-strategies: Material selection /Substitution /Selection of low-impact materials (2,3,5), Reduce weight (3,4), Reduce material usage / dematerialise / Waste source reduction by design (2,3), Design out toxicity /for substance reduction (2,4), Emotionally durable design /Classic design & stronger product-user relation /Design for product attachment (1,3,6), Design for variability (6), Design for reliability & robustness (6), Design for modularity (2,6), Design for disassembly /Use fewer joining elements (2,4,5).

Sources: (1) Ceschin and Gaziulusoy, 2016. (2) Ljungberg, 2007, cited in Chiu and Kremer, 2011. (3) Colby, 2011, cited in Adams et al., 2012. (4) Luttrupp and Lagerstedt, 2006. (5) Rossi et al., 2016. (6) van Nes and Cramer, 2003

The sub-strategies are often sub-ordinate to multiple strategies and the strategies have multiple associated sub-strategies. The strategy marked with an asterisk can be seen as a group of strategies. Note that biomimicry was also included by Ceschin and Gaziulusoy (2016), but we see this as a means to generate innovative ideas, rather than a strategy for sustainable product design. Excluding sub-strategies, aiming to include both social and ecological elements of sustainability and balancing comprehensiveness versus building-fast-to-learn-fast, we included the following strategies in our prototype: *Product-service system (PSS) design for sustainability, design for remanufacture, design for sustainable behaviour, design for the base of the pyramid, design for sustainable supply chains, and design for social innovation.* Through prototyping, we intend to learn and iterate our selection.

4 RESULTS: HOW TO PRESENT THE INFORMATION?

The analysis should also help users to focus on relative, rather than absolute, performance and should provide information in consistent terms (Gregory et al., 2012). Comparing alternatives, rather than evaluating a single option by itself, helps to mitigate for evaluability bias (Arvai et al., 2012), leads to higher rates of good decision-making (Gemünden and Hauschildt, 1985), better understanding of important principles (Dow et al., 2010), and faster decision-making (Eisenhardt, 1989). Furthermore, in order to reduce the potential for spurious confirmation, it is important to consider alternatives even when one option/reasoning seems obvious (Oswald and Grosjean, 2004).

The business value and sustainability value focus of our prototype are *ends-objectives* (as opposed to means-objectives), which helps to reduce anchoring bias (Arvai et al., 2012). We present the information about these values as qualitative description, which could also help project teams to learn about the respective values. Learning while selecting is important since capacity has been identified as a barrier to sustainable product development (O’Rafferty and O’Connor, 2010) and knowledge of the designers and engineers is important for succeeding with sustainable design (Bovea and Pérez-Belis, 2012; O’Rafferty and O’Connor, 2010; Short et al., 2012).

5 RESULTS: THE DECISION-SUPPORT PROTOTYPE

On the following two pages, we present the decision-support prototype - Figure 1.

Strategy	Potential sustainability value – How the strategy delivers sustainability value by contributing to better alignment (+) or misalignment (-) with the 8 sustainability principles across the lifecycle. Notes (⊕) are points of interest.								Potential business value																
	Supplier activities (from extraction to supplier-based manufacturing)		Manufacturing activities at focal company		Distribution & sales activities		Usage activities		End-of-life activities																
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
<p>PSS design for sustainability (d) is to design a system, a combination of products and services, to provide a function that addresses user needs in a more sustainable way⁴.</p>	+	⊕ _b	+																						Offers opportunity for differentiation from competitors, better addressing user needs, improved relationship with user, and better optimisation of costs across the system ² . These solutions often involve doing business in a different way, an internal transformation process and therefore require a basic 'stretch' and learning capability ³ .
<p>Design for the base of the pyramid (g) is to design to alleviate poverty whilst building new business opportunities - to design for (and with) the over 4 billion people whose income is less than 2 US\$ per day. To design product-service systems where the target group are also producers in the system and that address relevant challenges, such as inadequate infrastructure and poor access to financial services.⁴</p>	+	⊕ _e	+																						Purpose is not profit driven, but rather improvement of corporate image amongst the mature customer base ² , increased employee motivation, better access to recruiting markets, and learning about new rising markets ⁵ . The potential purchasing power of the base of the pyramid is 5 trillion US\$. Profitability depends on large volume, higher labour-share, low margin per unit, and high return on capital employed ⁶ .
<p>Design for sustainable supply chains is to design to promote sustainable supply chains by collaboratively including the supply chain management function in order to promote sustainable supply chains.</p>	+	⊕ _h	+																						Guards against material disruption ⁸ and decreases risk ¹⁰ . Development of inter-organisational capabilities that are particularly hard to imitate and thus can be a source of inter-firm competitive advantages ¹¹⁻¹² and also facilitate learning ¹³ . Increased trust in the supplier-buyer relationship increases the quality of information ¹⁴ and decreases transaction costs ¹⁵ . Relevant to those that govern the supply chain, have direct contact with the user, and design the product offered ¹⁶ , those held responsible for supply chains by external stakeholders such as consumers, NGOs and the media ¹⁷ . Particularly relevant to those at risk to disruption of supply (of key materials).
<p>Design for social innovation is the design of solutions (products, services, models) to solve social problems¹⁸ and enhance society's capacity to act¹⁹. In the USA it is often related to projects in developing countries, whereas in Europe it means co-designing with public servants or communities to develop solutions for local needs²⁰.</p>																									Design for social innovation is a collaborative endeavour and requires relationship building with a variety of stakeholders connected to the social issue in focus. Therefore, it can help businesses build social capital and strengthen their brand.
<p>Design for remanufacture is to design such as to facilitate returning a used product to a like-new useful condition (often with an associated warranty)²¹.</p>	+	⊕ _p	+																						Re-using parts gives material and manufacturing cost savings ²² and a steady supply of cheap spare parts ²³ . Actively designing for remanufacture can lead to increased efficiency and therefore increased savings ²⁴ . High potential for products with high value and durable parts, technological stability and potential to be upgraded ²⁵ . Address increasing environmental legislation on end-of-life ²⁶ . Particularly relevant product-service systems where the original manufacturer retains ownership of the physical good(s) ²⁷ .
<p>Design for sustainable behaviour is to design to influence user behaviour, including habits, to be more sustainable²⁴ ²²</p>																									Customer feels helped and understood, which can improve brand image. Particularly relevant for products with large sustainability impacts during usage, for example, mobile phones and jeans. The value is not realized if consumers feel overly forced into different behaviour ²⁴ .

Key to notes in sustainability value:

(a) Opportunity to decouple revenues from the sale of physical goods. Potential also for improved lifecycle management of products since the system of actors usually maintains ownership of the goods. Both of the above may lead to reduced demand for raw materials and manufacturing.¹⁻² (b) This dematerialisation reduces the need for extraction activities, and extraction activities are often socially problematic. As virgin resources become scarcer and competition increases, these activities may become less and less socially sustainable. (c) By providing offerings that more closely meet users' needs, there is potential for less waste from poorly designed goods. (d) The sustainability value is much more likely to be realised with design strategies for improved lifecycle management, such as design for sustainable supply chains and design for remanufacture.

(e) When communities at the base of the pyramid become (co)responsible for supply chain, production, distribution and sales activities, structural obstacles to social sustainability are reduced by creating income opportunities.³ (f) With poverty reduction as the purpose, social sustainability issues are naturally addressed. For example, improving health through water purification or nutrition based product services. By providing access to standard services like telecommunications, there is an increased access to information⁴ and therefore increasing opportunities in terms of local competence development and participation in shaping their social systems. (g) This strategy does not focus on ecological issues, but reducing poverty may also have positive indirect effects on the ecological system. For example, better sanitation means less water contamination. However, greater development could increase demand for fossil fuels. As clean technologies are harder to introduce in the mature market as they tend to disrupt existing infrastructure and legislation, the less developed markets at the base of the pyramid are considered great places to introduce emergent innovation.^{5,6}

(h) This strategy seeks to reduce misalignments throughout the supply chain by managing supplier relationships. The particular value realised depends on the actions taken. Examples include material, chemical and energy efficiency through direct management and also through supplier development initiatives.^{7,8,9,10} improved working conditions¹¹ and reduction of barriers to influence through inclusion of suppliers into a broadened decision space or re-conceptualisation of the value chain to also invite, for example, NGOs and local communities into decision-making processes.¹²

(i) This strategy seeks to solve social problems¹³, such as access to safe drinking water, or target behavioural change for social well-being¹⁴ and has its main focus on the consumers. Benefits are thus mostly social and occur at the usage phase. It is unclear if benefits are achieved in the other phases and they would be most likely project dependent. If a design for social innovation project targets the base of the pyramid, the sustainability benefits will likely be in line with the analysis of the strategy design for the base of the pyramid.

(k) Re-using parts removes the need to manufacture and even to extract or recycle the raw materials. This also reduces the transportation burden in the supply chain. (l) It also means that parts are not burnt or sent to landfill (Lund, 1984, cited in Hatcher et al., 2011). (m) Impacts of reverse logistics^{15,16}. However, it is possible for the reverse logistics to become more sustainable, for example as renewable energy sources become widely used, and thus remanufacturing with unsustainable logistics could be seen as a flexible platform. (n) There are some claims that remanufacturing brings skilled jobs close to the market where the product is sold. (p) Reduces the need for extraction activities, which are often socially problematic. As virgin resources become scarcer, these activities may continue to be less and less socially sustainable.

(q) This strategy seeks to influence users' habits (and other behaviour) to be more sustainable¹⁵. This is most often as an iteration of the current product and focused on ecological aspects, but can aim to influence behaviour more generally¹⁷.

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Figure 1. The decision-support prototype (2 pages, intended to be size A3).

6 DISCUSSION

We have designed a *prototype that provides information on the business and sustainability value of various sustainable product design strategies in order to help project teams to select which strategy/ies they will employ in a given project*. Selecting relevant strategies would hopefully enable project teams to work with sustainability in a way that delivers business value as well as significant sustainability benefits.

This prototype will now enable initial testing of the general approach of selecting sustainable design strategies according to their business and sustainability relevance to a given project. The details of the approach are being developed through an action research project with two companies - one using a design-thinking product development process and one using a stage-gate process.

We found no equivalent studies and therefore argue originality.

6.1 Learnings from designing the prototype

The sustainability value and business value differ across the strategies and users can therefore select strategies in a complementary way to achieve a range of benefits, or to enhance the benefits of another strategy. For example, for those that wish to explore PSS design for sustainability, designing for remanufacture enables realisation of the potential sustainability value of better end-of-life management and, simultaneously, the manufacturer maintaining ownership of the physical products (through use- or result-orientated product-service systems) enables realisation of the business value of design for remanufacture. Another example is that design for the base of the pyramid often involves designing product-service systems and therefore there is the potential to use PSS design for sustainability to further enhance the sustainability performance.

6.2 Limitations

Some of the strategies used in the prototype were difficult to define. We found general agreement in the literature on the definitions of design for remanufacture and design for sustainable behaviour, but there are many perspectives on the other strategies. We have therefore either chosen a relevant definition, or when needed derived our own definition.

When analysing the potential value of the strategies, it was difficult to collect evidence from empirical studies, particularly for the more amorphous strategies. The realisation of potential value also lies in the successful implementation of the strategy in a relevant context with various preconditions met. It is therefore not possible to definitively assess value, but rather we aim to indicate potential value, identified within literature, in a way that we consider is good enough for an early prototype that will be used to test and develop an approach.

Finally, our way of expressing the sustainability value is limited. A lifecycle perspective is only one way of looking at a product system. In future versions of the prototype, it would be interesting to also compare the strategies in terms of other ways of contributing to society's transition to sustainability.

6.3 Contribution

Our contribution is a decision-support prototype designed to be used by project teams to inform their selection of sustainable design strategies. We developed this analysis-based prototype in order to be able to develop and test ways to integrate the selection of sustainable design strategies into the early phases of product design. The suggested way to analyse and compare the sustainability value of design strategies is a contribution in itself.

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