DESIGN FOR AMELIORATION: FRAMEWORK OF DESIGN FOR SUSTAINABILITY TOOL

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ABSTRACT

Design for Sustainability (DfS) tools are used adjacent to a design process to determine the sustainability level of the proposed solution be it a product, service, or a combination of both. A DfS tool must assess all three pillars of sustainability: people, planet, and profit. Different types of DfS tools are cataloged and compared and the findings show that many of them are underdeveloped while others are still in a theoretical stage. Some underperform in one or two pillars of sustainability thus can only be categorized as partial DfS tools. These tools are then fitted into the framework of the human-centered design process due to its focus on the people pillar of sustainability which is often overlooked. While many tools are suitable to be used in one particular stage of a design process, analysis shows that only a small number of them are comprehensive enough to be used throughout the entirety of the design process. The versatility of different DfS tools is deemed essential because it allows designers to keep track of their projects at any point in the design process. A framework for a more comprehensive DfS tool is then proposed, called Design for Amelioration, with which designers assess the sustainability level of all pillars of sustainability at every stage of the design process.

KEY WORDS

Design for Sustainability tool; Human-Centered Design.

1. INTRODUCTION

The word ‘sustainable’ is often used to describe something good for the environment. However, it is an imprecise use of the word. Forming a locution of the word ‘sustainable’ with any activity should consider all three pillars of sustainability: people, profit, planet (ELKINGTON, 1998; GENNARI, 2000). Abiding by this nomenclature, design for sustainability can therefore be easily differentiated from eco-design, which focuses only on the environment. Studies demonstrated that an eco-design approach typically lacks the aspects of people and profit, whereas the DfS approach is more holistic and all-inclusive (CHIU; CHU, 2012; EDWARDS, 2010; KRYGIEL; NIES, 2008; REINDERS; DIEHL; BREZET,

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2012; SPANGENBERG; FUAD-LUKE; BLINCOE, 2010). In terms of innovation, the DfS approach cultivates both technological and social innovations where the eco-design approach typically focuses only on the technological dimension. DfS aims to re-discover other methods to satisfy a need while eco-design strives merely to re-design or reorganize products. Lastly, the outlook of eco-design is short-term while DfS is looking at the long-term scope (SPANGENBERG; FUAD-LUKE; BLINCOE, 2010).

While eco-design tools out there are in abundance (GÓMEZ-NAVARRO; CAPUZ-RIZO; BASTANTE-CECA; COLLADO-RUIZ, 2005), there are only a few DfS tools available. DfS tools assist designers as well as enterprises in guiding the design process so that they can properly claim that their design is indeed sustainable. This is a relevant subject because, in today's market, businesses release products that also have to compete on the basis of sustainability (HOSSEINPOUR; PENG; GU, 2015).

A comprehensive DfS tool should be able to be deployed at every stage of the design process so the rate of success of the proposed solution can be measured. This paper aims to investigate Design for Sustainability tools available to assist design activities. They are then fitted into the stages of human-centered design (HCD). HCD was chosen because it focuses on the one pillar of sustainability so often ignored: people. The reason for this is arguably due to the complexity of human beings, whether individually or in a group setting.

2. THEORETICAL FOUNDATION

Also known as 3E (Economics/Equity/Environment), the 3P (Profit/People/Planet) or 'triple-bottom-line' model of sustainability, clearly identifies the beneficiaries of a proposed solution. It recognizes all the necessary entities that must be counted in the effort to reach sustainability.

Some scholars have been proposing different models as opposed to the 3P model. Findeli critiqued the tri-polar model of sustainability and proposed a different one (2008). However, the proposed model is merely an effort to restructure instead of making a fundamental change to the elements of sustainability. In addition to the Triple Bottom Line (ELKINGTON, 1998), Thackara listed several frameworks for planning whole-systems with the sustainability concept in mind (2006), such as the Five Capitals Model – Natural, Capital, Social, Manufactured, and Financial Capital - along with the Twelve Features of a Sustainable Society (PORRITT, 2005), and The Natural Step framework (ROBÈRT, 2002). Even with these different models, the essential elements remain identical to the 3P model. However, it can be argued that these frameworks are quite totalitarian as they concern themselves with the design of societies as a whole. It would be challenging to abstract those all-encompassing frameworks into a well-functioning sustainable design tool. That would mean designers are not expected to design products and services anymore but rather expand their scope and design societal systems instead. Their scope is so large that it can present competency problems for the design field.

This is the reason why the 3P model is still relevant in assessing sustainability in product design, which is the identification of beneficiaries of a proposed solution. Designers can simply ask themselves, for instance, who or what would be benefitted from this proposed solution? When the proposed solution demonstrates to be beneficial to each pillar of sustainability, then it can be claimed to be sustainable.

In the area of product design specifically, a framework was proposed by Edwards (2010) which classifies key features of a product into five elements that not only consider the safety of the production process of the product but also take into consideration whether the product benefits local communities. Other than using a set of criteria, sustainability assessment in product design can be in a form of a tool or guideline. A number of DfS tools and guidelines are gathered and they are classified into two groupings: partial DfS and full DfS tools. This is based on their sustainability considerations. A partial DfS tool only considers one or two pillars of sustainability while a full DfS tool would consider all pillars. Table 1: builds on the DfS tools collected by Ahmad *et al*. (2018).

Tool	Description	Pillars of sustainability		
		Profit	People	Planet
Building Information Model (BIM)	Combines a wide range of information such as materiality, weather, and daylight with design software to enhance the feasibility of a design project and to measure their level of sustainability.	Yes		Yes
Theory of Inventive Problem Solving (TRIZ)	TRIZ is closer to an eco-design methodology than sustainable design	Yes		Yes
Integrated Ecodesign Decision Making (IEDM)	Applies environmental considerations across the three stages of product development	Yes		Yes
Environmentally Conscious Quality Function (ECQFD) and LCA Based Method	Based on ECQFD and LCA (Life Cycle Assessment)	Yes		Yes
Multi-aspect QFD for Environment / MQFDfE	Prioritizes improvement strategies to accomplish sustainable product development	Yes		Yes
Normative Decision Analysis Method for the Sustainability-based Design of Products / NDAMfSDP	Evaluates design alternatives and selects the most optimized model based on all lifecycle phases. Uses mathematical function	Yes		Yes
LCA Integrated with Monte Carlo Simulation	The main focus is end-of-life (reuse, recycle, reprocess of product)	Yes		Yes
Fuzzy Green - QFD	Combines Green QFD and Fuzzy Theory.	Yes		Yes
Integrated ECQFD – TRIZ – AHP Design Method	Finds best design criteria for a specific product.	Yes		Yes
Design framework for customized product-service system (DFfCPSS)	Uses AHP for configuration requirements and TRIZ to resolve conflicts of configuration. The framework is based on product customization and product service system	Yes		Yes
Lifecycle Design Strategies (LiDS)	Used to ratify if a product satisfies the eight strategies of eco-design. Highly qualitative, though does not reflect the real impact of a product on the environment	Yes		Yes
Guidelines and Regulations for Early Design for the Environment (GREEn Quiz)	A web-based application that determines which design decisions will have the highest environmental impacts and encourage sustainability in product design	Yes		Yes
Method for Sustainable Product Development (MSPD)	Development of eco-design tools		Yes	Yes
Fuzzy QFD	Based on two-phase QFD for mapping of sustainability requirements and design considerations	Yes	Yes	Yes
Sustainable Platform for Product Family Design (SPPFD)	The values of sustainability indicators are aggregated into a single sustainable value of a product. Optimized for product family or design of multiple products	Yes	Yes	Yes
Product Sustainability Index (ProdSI)	Generates a five-level ProdSI grounded on a set of product sustainability metrics. More suitable for manufactured products	Yes	Yes	Yes
Fuzzy Sustainability Evaluation Method (FSEM)	Decreases the complexity involved in product design decision-making. More suitable for manufactured products	Yes	Yes	Yes
Sustainable Product Design Assessment (SPDA)	Includes risks and benefits of each sustainability aspect. Not only assess the product itself but also the company and the manufacturing site itself. Suitable for designers and manufacturers	Yes	Yes	Yes
Design support system for machine tool sustainability index (DSS for MTSI)	Combines lifecycle analysis tools (LCC or LCA) within DSS	Yes	Yes	Yes
Integrated Robust Design Methodology (RDM)	Integrates RDM with sustainability principles and includes a lifecycle perspective of sustainability	Yes	Yes	Yes
Kathalys	Five step-phased approach with guidelines for future explorations to implementing new sustainable products and services	Yes	Yes	Yes
Sustainable Design-Orienting (SDO)	Aims to orientate system design process towards sustainable solutions (environmental, socio-ethical, economic)	Yes	Yes	Yes

Table 1: *DfS tools and the pillars of sustainability. SOURCE: prepared by the authors, based on Ahmad et al. (2018).*

Most partial DfS tools are heavily emphasized on only one pillar of sustainability: the planet. Even when they additionally consider other pillars, they tend to underperform at them. However, these tools have been gradually experiencing several transformations especially in the broadening of scope, boundary, and application. Today, they have seen the incorporation of other pillars of sustainability: profit and people (AHMAD; WONG; WONG; TSENG, 2018; VALLET; EYNARD; MILLET; MAHUT *et al.*, 2013). Some DfS tools are underdeveloped, either being still in the theoretical stage or underperform in a pillar of sustainability.

To ensure the generation of sustainable solutions, a comprehensive framework is needed to guide the entirety of the design process and assess its results.

3. METHOD AND DEVELOPMENT STRATEGY

The lack of consideration of the people aspect of sustainability in some of these tools indicates a need for a design guideline or tool which integrates the people aspect of sustainability better. The human-centered design (HCD) approach aims to create innovative solutions which focus on people. HCD underlines the particular effort of generating tailor-made solutions to satisfy the exact need and real desire of the target user. Characteristics of HCD affirm the value of human dignity because it seeks to support and strengthen it as they act out their lives in varied social-economic, political, and cultural circumstances (BUCHANAN, 2001). Three primary objectives are identified in the HCD approach: enhancing human abilities, overcome human limitations, and foster user acceptance (ROUSE, 1991). HCD is meant to tackle the issues of empathizing and lack of understanding. It is a process and the reason it is labeled as 'human-centered' is that it starts with the people it is designing for (IDEO.ORG, 2011). Solutions can include products, services, environments, organizations, and modes of interaction. The HCD process is divided into three stages: Inspiration, Ideation, and Implementation.

DfS and HCD, as design methodologies, have several disparities between them especially in their focus (PETTERSEN, 2015). Thus HCD can be considered to impede the principles of DfS. However, HCD can indeed be sustainable as long as enough attention is directed to the other two pillars of sustainability (HANINGTON, 2017).

4. RESULTS AND ANALYSIS

4.1. Comparison of available DfS tools

The reasoning behind fitting the tools within the HCD process is to ensure that the concept of sustainability is followed for the entirety of the design process. Table 2: shows the suitability of all available DfS tools with different stages of the human-centered design process, whether at the beginning of a design project (Inspiration stage), in the middle (Ideation), or at the end (Implementation). Several tools are excluded due to the uncertainty of which stage they can be used in. The tools are now grouped under 'partial' and 'full' types based on the identification already demonstrated in Table 1:

Type of DfS tool	Tool	Stages of the HCD process		
		Inspiration	Ideation	Implementation
Partial	BIM	Yes	Yes	Yes
	TRIZ	Yes		
	IEDM		Yes	
	ECQFD+LCA	Yes	Yes	Yes
	MQFDfE	Yes		
	NDAMfSDP	Yes	Yes	Yes
	LCA Monte Carlo	Yes		
	Fuzzy Green-QFD	Yes	Yes	
	Integrated QFDE	Yes		
	DFfCPSS	Yes		
	LiDS		Yes	
	GREEn Quiz	Yes		
	MSPD	Yes		
Full	Fuzzy QFD	Yes		
	SPPFD	Yes		
	ProdSI			Yes
	FSEM			Yes
	SPDA	Yes	Yes	Yes
	DSS for MTSI	Yes		
	RDM	Yes		
	Kathalys	Yes		
	SDO	Yes		

Table 2: *Suitability of Partial DfS and DfS tools in the stages of human-centered design process SOURCE: prepared by the authors.*

It is important to know the positioning of these DfS tools because it allows designers to keep track of their projects at any point in the design process. Most DfS tools are only suitable to be used in the early stages of the design process although four tools were found to be suitable to be implemented throughout the design process. Most full DfS tools are suitable to be applied either at the beginning or towards the end of the design process. For instance, the Sustainable Design-Orienting / SDO tool (VAN HALEN; VEZZOLI; WIMMER, 2005), was found to be a well-rounded tool that considers all pillars of sustainability and has assisted in generating sustainable solutions (**A world of sustainable ideas**, 2010). However, it is not suitable to be used at every stage of the design process. Only one tool was found to be a comprehensive full DfS tool and can be applied at each stage of the HCD design process, SPDA (HOWARTH; HADFIELD, 2006). However, it has quite a big scope as it assesses not only the proposed solution in question but also the manufacturing site and the manufacturing company. Therefore, using it can be a very energy-intensive as well as time-consuming task.

A good number of tools can only be utilized either at the early or late stages of the design process. When assessment can only be conducted at an early stage then only the intention can be measured. When done at the end then only the result can be assessed. A design project may be started with the best intentions but that does not always yield good results. Studies in other fields remark that it is a common mistake to judge results based on intentions (FRIEDMAN, 1975; SOWELL, 2008).

This study builds on the concept of sustainability as well as on the range of DfS tools available today.

4.2. Proposition: Design for Amelioration tool

The Merriam-Webster dictionary defines 'ameliorate" as "to make better or more tolerable". The origin of the word can be traced to the Late Latin word *melior,* which means 'better'. This word was chosen because it captures the spirit to improve and to grow better. Therefore, this framework of a comprehensive design for sustainability tool is titled Design for Amelioration, as it seeks to identify every improvement made on all pillars of sustainability.

The fundamental structure of this tool is an extrapolation of the three questions devised by Thomas Sowell, an American economist, social theorist, and a senior fellow at Stanford's University's Hoover Institution, when asked about the proper method to assess social policies. The questions are, "compared to what?", "at what cost?", and "what hard evidence do you have?" The fundamental ideas behind these questions were then conceptualized to develop a comprehensive tool for DfS.

The proposition is a DfS tool that considers all pillars of sustainability and can be utilized at the beginning, middle, and final stages of a design project. The tool is divided into three stages: Inspiration, Ideation, and Implementation, adhering to the HCD process. The first and second stages are prescriptive, thus can be classified as a set of guidelines. The third stage is descriptive as it presents and discusses the results as well as assesses the results. For this reason, the third stage serves more as a tool.

The layout of the tool is such to accommodate necessary actions required on every stage of the design project. Three circles are placed on the left representing each pillar of sustainability. As the stage progresses the circles expand indicating progress and growth. On the opposite side are shown actions required to be completed on each particular stage. More details on each stage are discussed in the following sections.

4.2.1. Inspiration

At the first stage, research has to be conducted on other existing solutions in the market. This means mapping existing solutions and see how they fare on each pillar of sustainability, using the template shown at the bottom right of Figure 3. The mapping should include at least two existing solutions to be compared to the proposed solution. Several important questions are included to guide the actions to be done at this stage.

For instance, if an existing solution is scored to be low impact in terms of people and profit but high in terms of the planet, then two dots would be placed on the inside area of the circle, close to the center of all three circles. One dot representing the high impact on the planet then placed towards the outer area, further from the center. These three dots thus make up a triangle. The same action is then repeated for the next existing solution as well as the proposed solution and thus generating three triangles of different sizes.

To pass this stage and move on to the next, the proposed solution must score higher than all existing solutions. Correspondingly, the triangle of the proposed solution has to be the largest one out of them all.

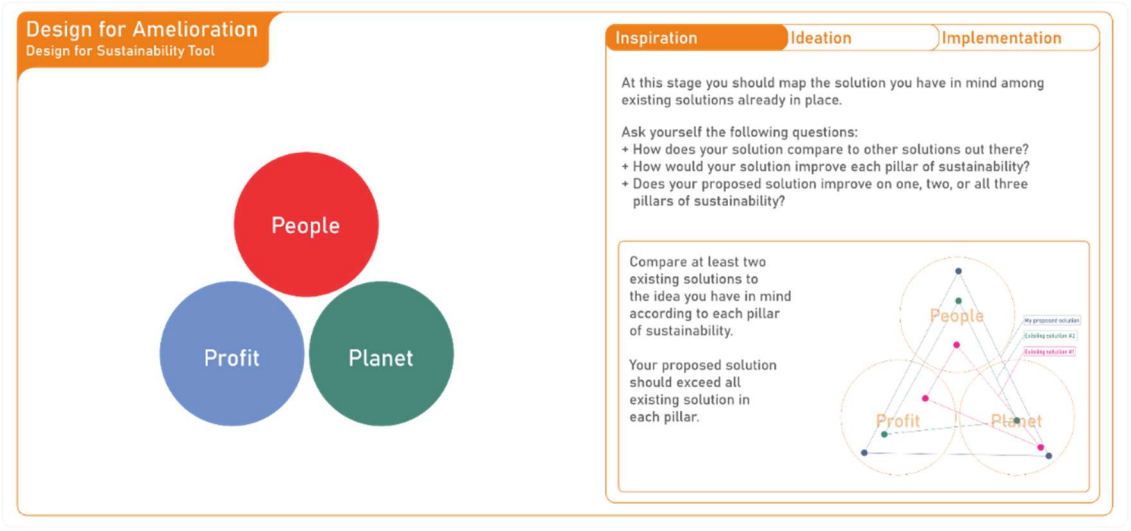

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Figure 1: *Mapping, comparison with existing solutions in Stage 1: Inspiration*

4.2.2. Ideation

Progressing to this stage indicates that the solution in mind does indeed benefit each pillar of sustainability. Therefore those benefits have to be identified along with their possible costs. A cost-benefit analysis can be constituted as a process of tallying up all the costs of the proposed solution and weigh them against all the projected benefits the proposed solution will bring. Using this method, the proposed solution can be scrutinized from opposing sides to determine whether it makes sense to bring it forth to the real world. It assists in making a proper decision. All costs and benefits can be listed in the table located on the bottom right in Figure 2:. All costs and benefits are grouped according to each pillar of sustainability. The benefits of the individual pillar must outweigh the costs to proceed to the last stage. Each circle of the pillars of sustainability expands as this happens.

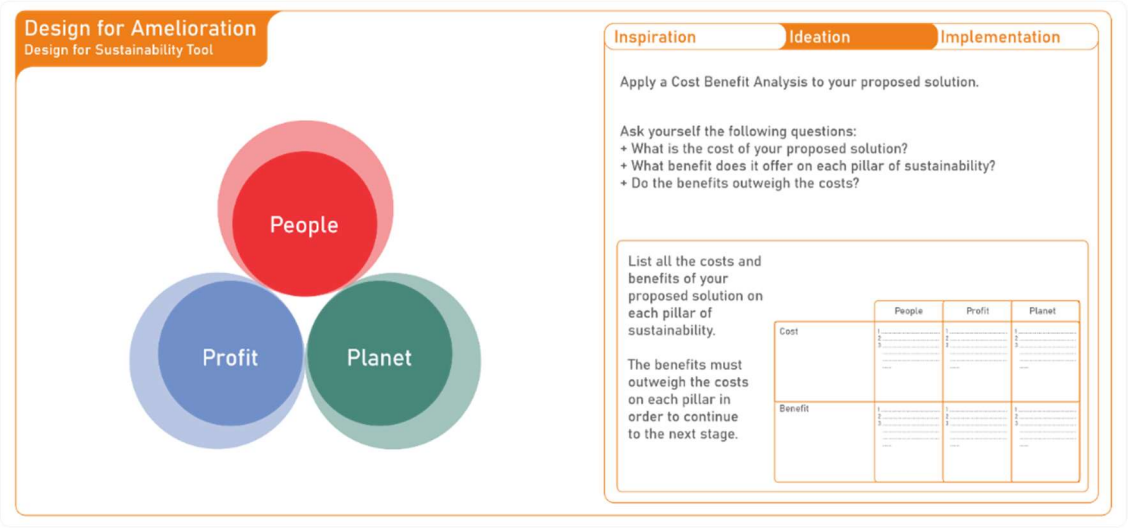

Figure 2: *Cost-benefit analysis in Stage 2: Ideation*

4.2.3. Implementation

At this point in the design process, the proposed solution has been implemented and tested in the real world. Data must be collected to determine whether the solution was successful or not. To be listed at this stage are all the improvements

on each pillar of sustainability as well as shortcomings of the solution. The improvements on each pillar must outweigh the limitations to conclude this stage.

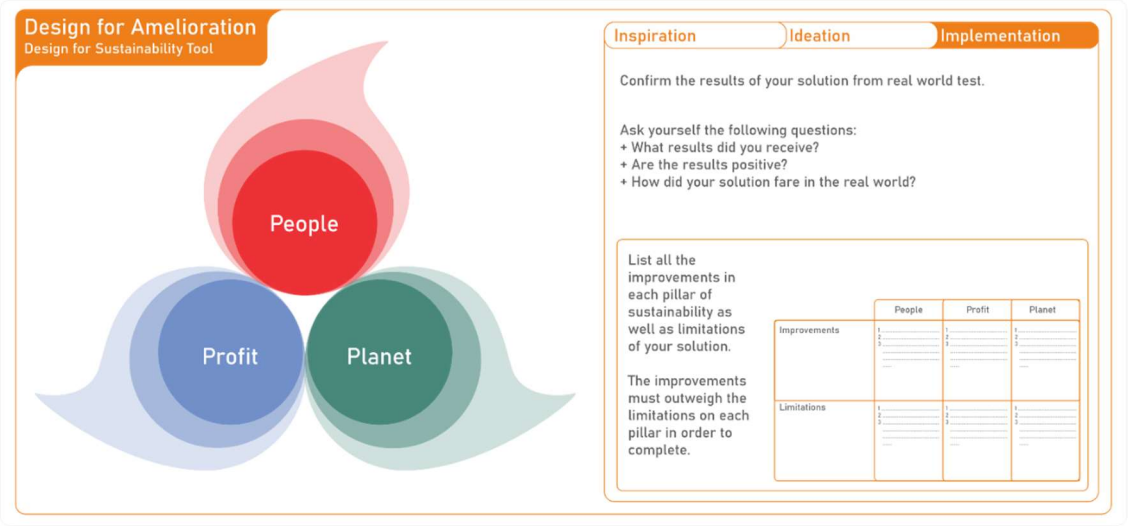

Figure 3: *Evaluation of results from a real-world test in Stage 3: implementation*

5. CONCLUSION

The increasing demand for sustainability in the field of product design has resulted in the development of various Design for Sustainability tools. Despite their 'sustainable' label, some DfS were found to lack crucial aspects of the concept of sustainability. Moreover, the majority of them cannot be employed at every stage of the design process. Therefore, a more comprehensive DfS tool that can be applied at every stage of the design process is needed to assist designers in assessing the sustainability level of their solution. A framework for such a tool has been proposed.

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