

INTEGRATION OF HUMAN-CENTERED DESIGN AND DESIGN FOR SUSTAINABILITY TOOL: PROPOSAL OF DESIGN FOR AMELIORATION TOOL

INTEGRAÇÃO DO DESIGN E DESIGN CENTRADOS NO SER HUMANO PARA FERRAMENTA DE SUSTENTABILIDADE: PROPOSTA DE PROJETO PARA FERRAMENTA DE AMENIZAÇÃO

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ABSTRACT

This paper proposes a new comprehensive Design for Sustainability (DfS) tool, called Design for Amelioration, with which designers can assess the sustainability level of all pillars of sustainability: people, planet, and profit, at every stage of the design process. DfS tools are used adjacent to the Human-Centered Design (HCD) process to determine the sustainability level of the proposed solution; be it a product, service, or a combination of both. HCD process is mainly chosen due to its focus on the people pillar of sustainability which is often overlooked in DfS tools. Thirty different types of DfS tools are cataloged and compared and the findings show that the majority of them are underdeveloped while others are still in a theoretical stage. The underperformed ones in one or two pillars of sustainability, thus, can only be categorized as partial DfS tools. These tools are then fitted into the known HCD's framework of inspiration, ideation, and implementation. 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.

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KEY WORDS: Design for Sustainability tool, Human-Centered Design, Design for Amelioration

RESUMO

Este artigo propõe uma nova ferramenta abrangente de Design para Sustentabilidade (DfS), chamada Design for Amelioration, com a qual os designers podem avaliar o nível de sustentabilidade de todos os pilares da sustentabilidade: pessoas, planeta e lucro, em todas as etapas do processo de design. As ferramentas DFS são utilizadas adjacentes ao processo de Design Centrado no Homem (HCD) para determinar o nível de sustentabilidade da solução proposta; seja um produto, serviço ou uma combinação de ambos. O processo de HCD é escolhido principalmente devido ao seu foco no pilar de sustentabilidade das pessoas, muitas vezes negligenciado nas ferramentas do DfS. Trinta tipos diferentes de ferramentas dfs são catalogadas e comparadas e os achados mostram que a maioria delas são subdesenvolvidas enquanto outras ainda estão em fase teórica. Os de baixo desempenho em um ou dois pilares de sustentabilidade, portanto, só podem ser categorizados como ferramentas parciais de DfS. Essas ferramentas são então encaixadas no conhecido quadro de inspiração, ideação e implementação do HCD. Embora muitas ferramentas sejam adequadas para serem usadas em uma etapa particular de um processo de design, a análise mostra que apenas um pequeno número deles é abrangente o suficiente para ser usado em toda a totalidade do processo de design.

PALAVRAS-CHAVE: Ferramenta design para sustentabilidade, design centrado em humanos, design para amenização.



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, planet, and profit (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; SPANGENBERG; FUAD-LUKE; BLINCOE, 2010). In terms of innovation, the DfS approach cultivates both technological and social innovations whereas the eco-design approach typically focuses only on the technological dimension. Design for Sustainability (DfS) aims to rediscover other methods to satisfy a need while eco-design strives merely to redesign 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 to the design field 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. In addition, the inadequacy of recruiting existing DfS tools became apparent to the researchers while running a study on sustainable service-product solutions working with communities. This paper aims to investigate DfS tools available to assist such design activities. As such, the tools 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. The relationship between them is illustrated in Figure 1.

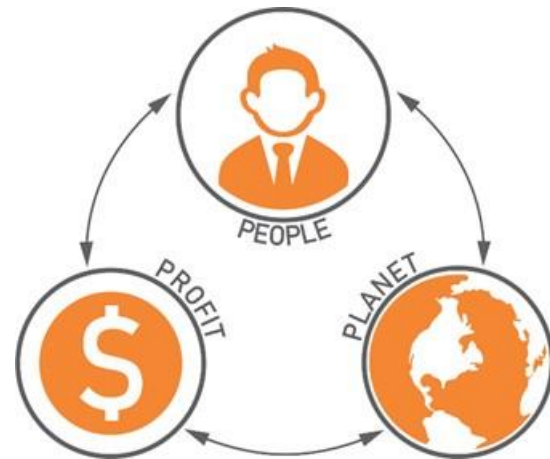


Figure 1: Triple-bottom-line model of sustainability. Source: Authors, reproduced from (ELKINGTON, 1998)

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). Basing it Steiner's 'social three folding principles (HOUGHTON; STEINER, 1996), he merged economics and ecology (profit and planet, respectively) into 'comprehensive economics', while splitting society (people) into 'human creativity' and 'social equity'. This proposition was merely an effort to restructure for better understanding 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 (ROBERT, 2002). Even with all those different models, the essential elements remain identical to the 3P model. Moreover, 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 only expected to design products and services anymore but rather expand their scope and design socio-technical or even the

earth-centric socio-technical systems (CESCHIN; GAZIULUSOY, 2020) instead. The 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 all three pillars 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 criteria of healthy for consumers, economically viable, environmentally sound, safe for workers, and benefit to local communities. That includes considering the safety of the production process of a product.

Other than using a set of criteria, sustainability assessment in product design can take a form of a tool or guideline as well. Hence, a number of DfS tools and guidelines were gathered and classified into two groupings: partial DfS and full DfS tools, building on the study done by Ahmad *et al.* (2018), in which recent and emerging product design tools were reviewed and grouped. Using this technique, tools that only consider one or two pillars of sustainability were classified as partial DfS tools and correspondingly tools that consider all pillars as full DfS tools. The study aimed to enhance understanding and it was conducted through the classification of 21 tools based on their sustainability considerations. Moreover, the nature of each tool was identified (whether they use quantitative or qualitative methods) and their level of compatibility at different stages of the design process determined.

This paper expands on the study of Ahmad *et al.* (2018) through the addition of 9 more tools to the table. This study adheres to their classification and identification in the analysis of the tools added. The list is now expanded to 30 DfS tool (Table 1), through the addition of Building Information Model / BIM (KRYGIEL; NIES, 2008), Theory of Inventive Problem Solving / TRIZ (RUSSO; SERAFINI; RIZZI, 2016), Integrated Ecodesign Decision Making / IEDM (ROMLI; PRICKETT; SETCHI; SOE, 2014), Lifecycle Design Strategies / LiDS (LIU; ZHAO, 2020), Ten Golden Rules (LUTTROP; LAGERSTEDT, 2006), GREEN Quiz (WISTHOFF; DUPONT, 2016), Sustainable Product Design Assessment / SPDA (HOWARTH; HADFIELD, 2006), LCSA (GUINÉE, 2016), Kathalys (LUITEN; KNOT; VAN DER HORST, 2001), and Sustainable Design Orienting / SDO (VAN HALEN; VEZZOLI; WIMMER, 2005).

Table 1: DfS tools and the pillars of sustainability. Source: Authors

Tool	Description	Pillars of Sustainability		
		Profit	People	Planet
Method for Sustainable Product Development (MSPD)	Development of eco-design tools		Yes	Yes
Multi-objective Material Selection Method (MMSM)	Based on the integration of artificial neural networks with genetic algorithms	Yes		Yes
Environmentally Conscious Quality Function and LCA Based Method (ECQFD+LCA)	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 (NASDOP)	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
Integrated ECQFD – TRIZ	Finds best design criteria	Yes		Yes

– AHP Design Method	for a specific product.			
Benchmark-based method that integrates QFD and LCA	Selects best design-based on values of quantitative sustainability metrics	Yes		Yes
Fuzzy Green - QFD	Combines Green QFD and Fuzzy Theory.	Yes		Yes
Integrated QFDE	Integrates QFDE with fuzzy Decision Making and Evaluation Laboratory and Fuzzy Analytic Network Process	Yes		Yes
Integrated approach based on QFDE and modularity	Gives a variety of products (modularity concept) instead of one design	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

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
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	Yes		Yes

	environmental impacts and encourage sustainability in product design			
Design support system for machine tool sustainability index (DSS for MTSI)	Combines lifecycle analysis tools (LCC or LCA) within DSS	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
Integrated Product Lifecycle Management (Integrated PLM)	Based on the utilization of PLM and LCM (Lifecycle Management)	Yes	Yes	Yes
Cost-benefit Analysis (CBA) based life cycle sustainability assessment (LCSA)	Shows the connection between three tools (LCA, LCC, and CBA) and a framework for integration is proposed	Yes	Yes	Yes
Integrated Robust Design Methodology (RDM)	Integrates RDM with sustainability principles and	Yes	Yes	Yes

	includes a lifecycle perspective of sustainability			
LCSA	Integrated LCA, LCC, and S-LCA	Yes	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
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
Kathalys	Five step-phased approach with guidelines for future explorations to implementing new	Yes	Yes	Yes

	sustainable products and services			
Sustainable Design-Orienting (SDO)	Aims to orientate system design process towards sustainable solutions (environmental, socio-ethical, economic)	Yes	Yes	Yes

Eighteen DfS tools were categorized as partial as they are heavily emphasized on only one pillar of sustainability: the planet. Even when they additionally consider other pillars, they tend to underperform at them. For instance, LiDS, which provides eight strategies for eco-design, lacks at both people and profit pillar of sustainability. 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). There were twelve tools identified with full DfS considerations. Nevertheless, most are either underdeveloped, inadequate or being still in the theoretical stage and underperforming in any pillar of sustainability, similar to what the earlier study concluded (AHMAD; WONG; WONG; TSENG, 2018).

3. METHOD AND DEVELOPMENT STRATEGY

To ensure the generation of sustainable solutions that encompass all pillars of sustainability, a comprehensive framework is thus needed to guide the entirety of the design process and assess the results from beginning to end. 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. For this reason, the attention was turned to Human-Centered Design (HCD) approach, which aims to create innovative solutions focusing 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 were identified in the HCD approach: enhancing human abilities, overcoming human limitations, and fostering 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 because it starts and ends 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 (Figure 2).

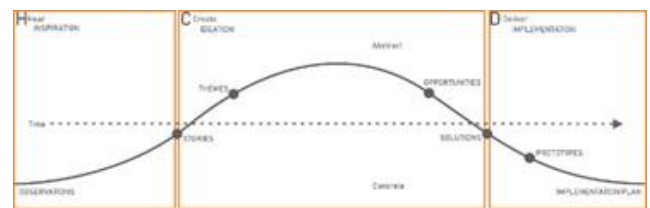


Figure 2: Three stages of the Human-centered Design process

Source: Authors, based on IDEO.org (2011)

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

4. COMPARISON OF AVAILABLE DESIGN FOR SUSTAINABILITY 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). Seven tools were excluded due to the uncertainty of which stage of the design process they can be used in. Therefore, out of 30 tools cataloged previously in Table 1, only 23 are included in Table 2. The tools are now grouped under ‘partial’ and ‘full’ types based on the identification already demonstrated in Table 1.

Table 2: Suitability of partial and full DfS tools in the stages of the Human-centered Design process. Source: Authors

Type of DfS tool	Tool	Stages of the HCD process		
		Inspiration	Ideation	Implementation

Partial	MSPD	Yes		
	ECQFD+LCA	Yes	Yes	Yes
	MQFDfE	Yes		
	NASDOP	Yes	Yes	Yes
	LCA Monte Carlo	Yes		
	Fuzzy Green-QFD	Yes	Yes	
	Integrated QFDE	Yes		
	DFFCPSS	Yes		
	BIM	Yes	Yes	Yes
	TRIZ	Yes		
	IEDM		Yes	
	LiDS		Yes	
	GREEN Quiz	Yes		
Full	DSS for MTSI	Yes		
	ProdSI			Yes
	FSEM			Yes
	Integrated RDM	Yes		
	LCSA		Yes	Yes
	Fuzzy QFD	Yes		
	SPPFD	Yes		
	SPDA	Yes	Yes	Yes
	Kathalys	Yes		
SDO	Yes			

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: Building Information Model, Environmentally Conscious Quality Function

and LCA Based Method, Normative Decision Analysis Method for Sustainability-based Design of Products, and Sustainable Product Design Assessment. Among them, only SPDA is a full DfS tool.

The Sustainable Design-Orienting / SDO toolkit (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 for challenges in sustainable food systems, sustainable mobility systems, and sustainable health/well-being systems at the LeNS (Learning Network on Sustainability) Student Design Competition 2010 (A world of sustainable ideas, 2010). However, it is not suitable to be used beyond the early stages of the design process. As a tool, it can be utilized to demonstrate the commitment to sustainability at the beginning of the design process but not at the subsequent stages of the design process.

SPDA (HOWARTH; HADFIELD, 2006), a tool that was found to be a comprehensive full DfS tool, can be applied at each stage of the HCD design process but has a large scope. It assesses not only the proposed solution in question but also the manufacturing site and the manufacturing company. Therefore, using it can be an energy-intensive and time-consuming task.

Since most tools were found to be suitable for use at the early stages, then a proper assessment can only be conducted at the early stages. Therefore, assessment can only be placed on the intentions. A design project may start with the best intentions but that does not always yield good results. In the case with several other DfS tools which can only be deployed at the late stages of the design process, then only the results can be assessed. Studies in other fields remark that it is a common mistake to judge results based on intentions (FRIEDMAN, 1975; SOWELL, 2008). Thus, it is imperative to bridge the gap between the intention and the result, input with output.

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

Design for Amelioration is envisioned to be a Design for Sustainability (DfS) tool to assist and guide designers to adhere to the concept of sustainability. It is a comprehensive DfS tool because it considers every pillar of sustainability: profit, people, planet. Using this tool, designers can exercise care upon each aspect of sustainability and ultimately would be able to claim their solution sustainable.

The tool is divided into three stages, adhering to the stages of Human-Centered Design. At each stage, different kinds of assessments are applied. The assessments for each stage were inspired by Sowell's three questions. Thomas Sowell is an American economist, social theorist, and senior fellow at Stanford University's Hoover Institution. His writing ranges from social policies on ethnic groups, education, and decision-making to classical economics and children perceived as having disabilities. He has authored more than 50 books on those various subject matters.

The fundamental structure of this tool is an extrapolation of the three questions devised by Sowell asking about how to assess social policies. The questions are, "compared to what?", "at what cost?", and "what hard evidence do you have?" (BARNES, 2005). The fundamental ideas behind these questions were then conceptualized to develop a comprehensive tool for DfS. These questions are essential because they fill the gap between conception and realization. Between intention and result as well as input and output. They serve as a bridge between imagination and reality. The first question requires an act of research by investigating what is already out there in the real world. The second question raises the matter of possible implications that might arise from an action. Whether it is indeed something desirable or at least can be endured. The last question evokes an act of evaluation. Ultimately, these questions help reconcile intentions with consequences.

Since this proposition is for a DfS tool that considers all pillars of sustainability that can be utilized at the beginning, middle, and final stages of a design project, it 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 at every stage of the design process. Three circles are placed on the left representing each pillar of sustainability. As the stage progresses the circles expand indicating progress and growth. The opposite side shows a number of actions to be completed at each stage. More details on each stage are discussed in the following sections.

5.1 Stage 1: Inspiration

At the first stage, research has to be conducted on other existing solutions in the market. This means mapping out existing solutions and seeing how they posit 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 proposal the designer had in mind. By laying out how existing solutions perform in each pillar of sustainability, designers can adjust their proposals accordingly. For instance, an existing solution might severely lack in terms of the people pillar of sustainability. Hence, designers can modify their proposal into something which exceeds that existing solution in that particular pillar of sustainability. This is possible because this is the beginning of the design process, where the proposal is still adjustable or modifiable.

When an existing solution scores low 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, closer towards the center of all three circles. One dot representing the high impact on the planet then is placed towards the outer area, further from the center of the circle. Those three dots thus make up a triangle. The same action is then repeated for the next already existing solution as well as the proposed solution and thus ultimately generates three triangles of different sizes.

At this stage, at least two existing solutions must be compared to the idea they had in mind. A set of possible questions to be used at this stage are provided to help the designers in forming the triangles: "How does your proposed solution(s) compare to other solutions out there?", "How does your proposal improve each pillar of sustainability?", and "Does your proposal improve on one, two, or all three pillars of sustainability?"

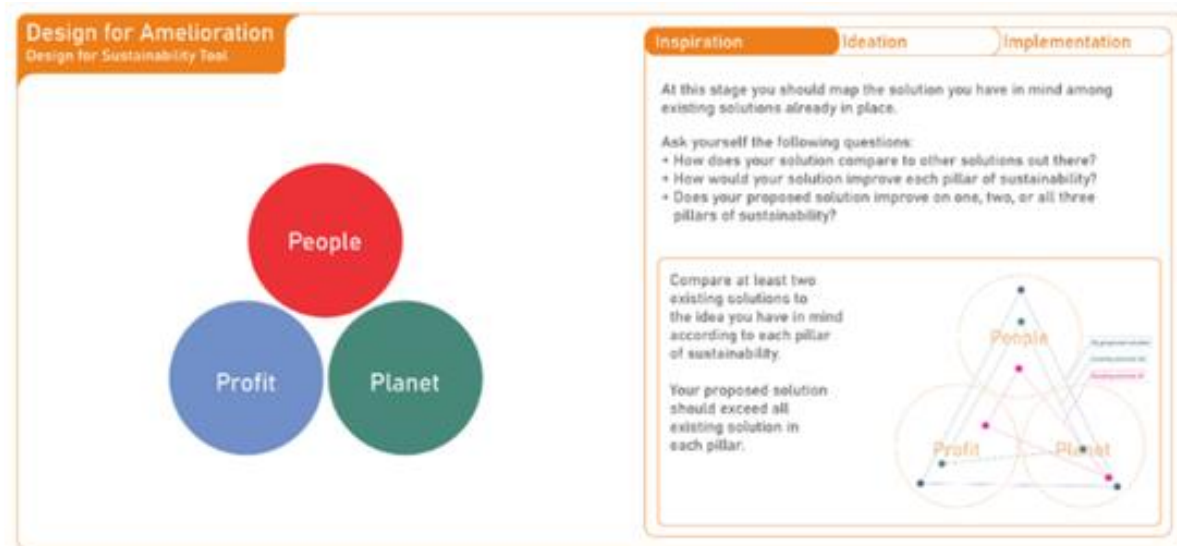


Figure 3: Mapping, comparison with existing solutions in Stage 1: Inspiration. Source: Authors

To pass this stage and move on to the next, the proposed solution must score higher in all pillars of sustainability compared to all existing solutions. Correspondingly, the triangle of the proposed solution has to be larger compared to other triangles formed from other existing solutions.

By juxtaposing existing solutions and their impact on people, profit, and the planet, designers can determine which pillar(s) of sustainability were being underserved by existing solutions. Consequently, this can inform designers to fine-tune their proposed solution to surpass all existing solutions on all pillars of sustainability.

5.2 Stage 2: Ideation

Progressing to this stage indicates that the intention 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 weighing 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 4. All costs and benefits are grouped according to each pillar of sustainability.

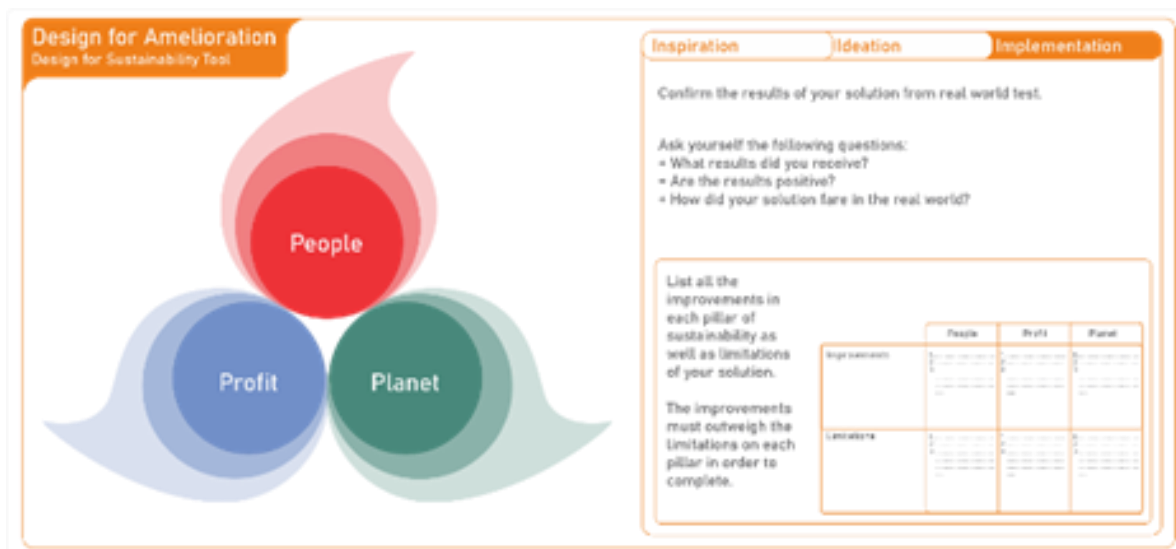


Figure 4: Cost-benefit analysis in Stage 2: Ideation. Source: Authors

To help designers identify the benefits and the costs of their proposed solutions, the following questions are provided: “What is the cost of your proposed solution?”, “What benefits do your proposed solutions offer on each pillar of sustainability?”, and “Do the benefits outweigh the costs on each pillar?”

To conclude this stage and move on to the last stage, the benefits must outnumber the costs in each pillar of sustainability. Each circle of the pillars of sustainability expands as this happens.

By laying out every identifiable cost and benefit associated with their proposed solution, designers can reveal the value of the proposed solution and at the same time, identify all possible implications that might come with the introduction of the solution into the real world.

5.3 Stage 3: Implementation

At this point in the design process, the proposed solution must have 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 (Figure 5).

The following questions are provided to identify improvements and limitations: “What results did you receive?”, “Was the solution impactful?”, and “How did your solution fare in the real world?”

By listing all improvements and limitations in each pillar of sustainability, designers can easily identify the precise improvement their solution brought in the real world as well as the limitations attached with their solution. The improvements on each pillar must outweigh the limitations to conclude this stage. The final shape of the three pillars of sustainability is achieved when this last stage is completed. Using the tool, designers can ultimately claim that their design is indeed sustainable as it passes through three stages of scrutiny involving all three pillars of sustainability. This means that the whole concept of sustainability was adhered to from the beginning, middle, and final stages of the design process.

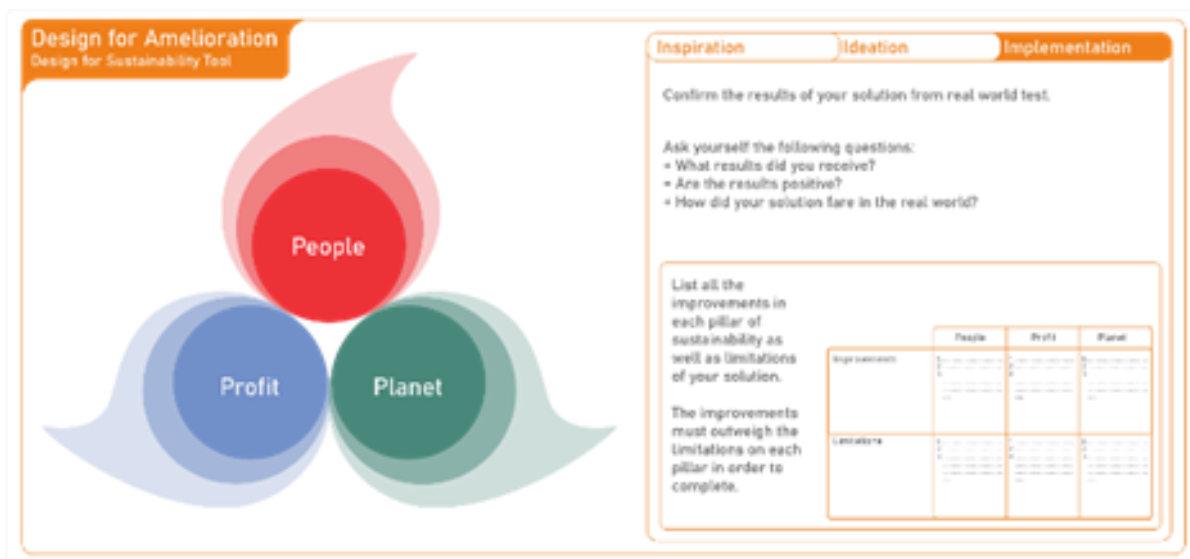


Figure 5: Evaluation of results from the real-world test in Stage 3: Implementation. Source: Authors

6. CONCLUSION AND FURTHER RESEARCH

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 be lacking 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 of Design for Amelioration for such a tool has been proposed.

This framework proposal is a graphic illustration of the envisioned fully functioning DfS tool. It has not

been prototyped to perform calculations or estimations. This framework needs to be developed further for it to be classified as a functional DfS tool that is ready to be used by others and benefits designers and design researchers.

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