SUSTAINABILITY INNOVATION IN EARLY PHASES

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ABSTRACT
Sustainability is a complex but extremely important issue. To achieve a new industrial revolution that focuses on sustainability, we need innovation. Merely improving our technologies and our habits will not save our planet from its current gradual degradation.
In recent decades many Eco-tools have been developed; this paper evaluates some of the most used methods, how they help to consider sustainability in the product development process and identify important and missing characteristics, arguing that many eco-tools were experienced by the companies as too complex and time-consuming and often not aiding a radical innovation process. These characteristics guided the development of a framework with creative methods for sustainability driven innovation based on a multidisciplinary workshop approach. It focuses on analyzing customers from a sustainable viewpoint, understanding their real needs, using ideation tools to generate ideas in areas not usually considered in current eco-tools, e.g. changing customer behavior or the business model. The method was developed, tested and evaluated in an iterative approach over a six-month period.

Keywords: Sustainability, Product Development, Radical Innovation

1 INTRODUCTION
In order to meet their own needs, humankind have made an unprecedented consumption of the Earth's resources in the last century. This has led to the well being of many but on the other hand an increasing of pollutions, the weakening of the Earth's resource capacity and a great gap between nations, especially the so-called 'northern world' and 'southern world' countries [1].
In the latest decade many concerns have been made around the topic of sustainability, that is how to combine the well being of society, economic development and the environment. Of course, industry is asked to play a great part in this process, increasing the environmental efficiency of the products by a factor between four to ten [2] [3].
To reach this over all ambitious goal, we need radical innovations. We need to build a new industrial revolution, as radical as the one in the 19th century, with a radical change of how we use resources, design and use new products, and change the notion of social well-being and economic growth.
That being so new challenges for the current designer are emerging. In fact, in the design phase lies the major responsibility of the future environmental and social impact of the designed product. Bruce Mau once described the need for innovation regarding sustainable design: "*If we do things that are damaging the environment, it's because they are stupidly designed, we do not need to do that.*"[4]. He concludes that we have just left out the environmental issues from the equation when we designed products. Jantschgi and Mann [5] argue that the biggest leverage regarding the environmental responsibility of a product is in the development phase. Even a small amount of time more expended in this stage can ensure a huge decrease of the total life cycle's environmental impact. By these conclusions, our research focuses on the product development process.
Although considered a very important issue by governments, mass media and population, effective sustainability implementation in society is still difficult to achieve, from both a technical and behavioral standpoint [6]. People often confuse the quality of life ('more is better' concept [1]), misunderstanding between economic growth and consumption (the 'old growth theory' as claimed by Romer [7]), and an unconscious mindset that there is no possibility to reduce resource consumption and improve the quality of life for everyone.
In the last decade, many tools have been developed to consider sustainability during the product and service development process. According to Bygget and Hochschorner [8], Knight et al. [9], and Thompson [10], the existing methods currently present some weak areas that limit their effective use in industry. As claimed by Lagerstedt [11], "*the most important thing for the environment is not the results of these methods, but actually doing something in reality*". She also argues that there is a need

for a method that guides the user to represent the functional and environmental characteristics in the very early stages of the product development process.
This paper presents a review of existing methods for sustainable design and their shortcomings, as well as the rationale and characteristics for an easy-to-use method for sustainable design. The paper also proposes a facilitated workshop method - Sustainability Innovation Workshop (SIW).

2 METHOD FOR DEVELOPMENT OF THE FRAMEWORK

The work described in this paper is based on a Master Thesis [12] and also builds on previous work done in Team Innovation and on methods for creative multi-disciplinary workshops done at Luleå University of technology [13].
The method described in this paper is based on an analysis of current Eco-tools, the actors involved, and finding drawbacks and delimitations of existing methods. These results form the rationale and characteristics for a method that is designed to be used very early in the product development process, challenging both the technological solutions and the needs and behaviors of users.
From the characteristics and previous work, a method developed in an iterative way is proposed, where tools and methods have been continuously designed, tested, evaluated and improved.

2.1 Delimitations

The research focuses on product development in industry, though we argue that there are other important actors, such as municipalities, governments, non-governmental organizations and non-profit organizations (the reasons will be further described in section 4).

3 THEORETICAL FRAMEWORK

This section describes the theoretical framework for the research presented and consists of three important areas. The advantages and problems of multi disciplinary teams for innovation are put into context; methods for facilitating multi disciplinary teams will be focused upon; and existing methods for sustainable design and Eco design will be reviewed.

3.1 Advantages and problems of multi disciplinary teams

Introducing several disciplines into the development of products increases the probability for break through innovation [14], though the heterogeneity in the team can increase the collaboration burden; it is far more troublesome to communicate and get a common understanding in a heterogeneous team than a homogenous team [14, 15]. A homogenous team is also more prone to groupthink [16]. Team members come from different disciplines with different ‘thought worlds’ [17] and bring in their expertise to the team, but at the same time their ‘thought worlds’ complicates communication. Also the grounding - the process of reaching a common understanding to the problem takes more time in diverse teams due to the contrasted understanding of problems, ideas and solutions:
The contrasted understanding may be seen as a waypoint or perhaps a crossroad, where the path can lead towards creating a shared understanding or towards even more divergent conflicting understanding, i.e. the team may either have consensus or conflict. In a sense, the contrasted understanding is where you step out of the comfort zone.[18 pp. 60-61].
This contrasted understanding is essential to the creative flow [18 p. 64] and acts as an inspiration where innovations may occur. It is important to be aware of the problems above; management and facilitation of the team process are important, otherwise these diverse teams may perform worse than a homogenous team [19].

3.2 Facilitating multi disciplinary innovation workshops

At Luleå University of Technology, a method for collaboration in multi-disciplinary team innovation has been developed [13]. The method tries to solve some of the problems mentioned above and is based on an interactive and highly collaborative workshop aided by a facilitator.
The role of the facilitator is to be an expert of the process and the method used in the process, not an expert of the particular workshop topic. The facilitator is also responsible for the design of the workshop processes (what happens before, during and after the event). To achieve a better possibility for innovation, it is important to analyze the diversity and knowledge represented in the team, is there any missing competencies, do wee need to bring in experts, customers that provides a wider knowledge base. An important characteristic of the facilitator is the ability to create involvement,

engagement and commitment [20]. The facilitator also guides the team in the most promising direction and explains and enforces the 'rules of the game'. Other important characteristics include the ability to encourage people to step outside of their comfort zone, and to encourage personal reflection.
The method is based on a three-step process, first highlighting the current situation – *Now*; the preferred situation - *Wow!*; and finally how this can be solved - *How?* These methods are iterated from different levels of complexity, different focuses and different points of view. For each iteration, an increased knowledge about the problem and the product is gained.
The workshop is designed to be interactive and involve all participants, and it is important to encourage different views. Throughout the workshop the results from each step are visualized on large facilitation posters, enabling an overview and easy access to all the previous results of the workshop. The workshop method has been continuously tested and evaluated in industry over the last four years, with very good feedback from industry participants [13].

3.3 Existing methods for sustainability

Bygget and Hochschorner [8] analyzed 15 different Eco-design tools that are currently used in industry to prescribe design alternatives, assess environmental impacts or to compare environmental improvement alternatives. The survey concludes that all analyzed tools can be complemented with other methods and tools based on strategic planning towards sustainability. Eco-design tools will then become useful to support the daily practice of product development. However, according to Bygget and Hochschorner, an Eco-design tool should also include a valuation and have a life cycle perspective to become a rational tool that can support a sustainable design.
Lagerstedt [11] evaluated nine Eco-tools, and analyzed the focus, purpose, if the assessment is qualitative or quantitative, and in particular, if the tool can be used in the early or late stages of the product development process. The survey concludes that there is a lack of methods to represent and balance product functionality and environmental aspects during the very early phases of the product development process. In other words, tools and methods that can aid in identifying and describing basic environmental and functional characteristics of different product concepts are needed.
In one of the most significant works in this field, Tischner at al. [21] analyzed several software Eco-tools to highlight how they deal with environmental problems, come up with ideas and select solutions, and consider product and market aspects in a sustainable perspective. Knight et al. [9] also confirm these conclusions in a survey among several companies, ranking the actual use of the Eco-tools. A trend was identified, where sustainability tools are now even integrated into commercial CAD systems such as *SolidWorks Sustainability* module [22]. These tools provide an easy access to LCA analysis and the Environmental Impact of parts and assemblies.
Another important issue was to identify how these surveys were used in different types of companies (large, medium and small) and the kinds of actors involved (i.e. governments, municipalities, NGO and NPO). As claimed by Hallstedt **[**23**]**, a survey among Swedish small and medium-sized Enterprises (SMEs) revealed a difficulty for them in implementing Eco-tools in the product development process. The main reason was that they considered the Eco-tools too complicated and time consuming, perhaps for the reason that these tools were initially created and developed in large companies. The survey demonstrates a good awareness by the SMEs to increase the environmental efficiency of their products and services, despite the difficulty in using tools to aid this process.

4 IDENTIFYING THE CHARACTERISTICS OF A SUSTAINABLE INNOVATION METHOD

In this chapter, the results of the literature analysis are presented, in order to find out some important characteristics of a method for sustainability, some guiding questions has framed the analysis:

- Why we need a method for sustainability?
- When in the product development process are these tools most important?
- What should be the performance characteristics of such method?
- How should the method help the companies/organizations?

4.1 When to use the method in the product development process

As stated in the introduction, the biggest environmental responsibility for the entire product life cycle lies in the product development process [5]. We conclude that the same result can be drawn *within* the

product development process as well, in which the first phases (according to the product development scheme proposed by Rozenburg and Eekels **[**24, p.13**]**; formulating goals and strategies, product policy, generating and selecting ideas) are the most important to decide the total future environmental and social impact of the product.
Therefore a method where sustainability is fore fronted should be integrated very early in the product development process [23], in order to avoid future environmental problems and furthermore to understand how a sustainable design could lead to new opportunities, such as new markets, cost savings etcetera.

4.2 Purposes

Every product is designed in order to satisfy the client's needs. So one of the first phases of a method for sustainability is to understand the customer's expectations in order to drive the innovation process. Just once we have clarified them, we can satisfy these needs in a sustainable manner. Just to give an example, the outcome from the workshop could be the understanding that a customer does not want a heater, but what he wants is warmth, and that is what he is willing to pay for. This could lead us to build an innovation in which we do not sell our heater, but in which we lease it to the customer.
Once we have figured out the real needs of our customer, we can go through the innovation process. We claim that this process should aid the product development team to find ideas along three dimensions. This concept is explained by the 'sustainable innovation box', see Figure 1.

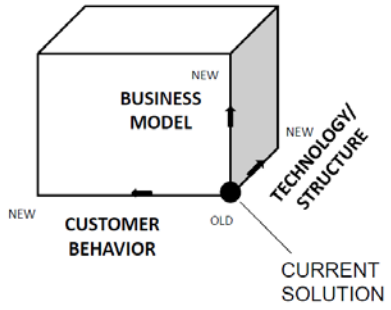

Figure 1 Sustainability Innovation box

These three dimensions are: changing the technology/structure of the product, modifying the business model or changing the user's culture and behavior.
As an example: bike sharing is an innovation in which there is not any improvement in the technology or the structure of the product (we have bicycles since almost two hundred years), but what change is the business model (the bicycle are not sold, but leased) and the user's behavior (customers have reached the choice to use bikes instead cars).
Is very important to help the team to explore all this three paths of innovation, especially the business model (for instance, shifting from a product selling to a product-service system) and the user's behavior. While in a product development team is in theory easy to think about changing technology and structure, difficulties emerge when the team wants to think 'out of the box' including the other two paths of innovation. This for many reason. They can be addressed to the cultural background of the team members (predominantly engineers or with technical formation in any case) but also to an often unintentional manner to think always with the current ways of making business and consuming products.
According to Mont [25], Manzini and Vezzoli [26], PSS opportunities from both an environmental and profitability point of view are not yet well explored in the companies. A method for sustainability might, highlighting environmental concerns when designing products, help a product development team to discover and analyze new ways to make business and at the same time to reduce the environmental impact of the product.
Finally, such a method must comprehend tools to assess the final solutions, discovering possible cases of 'hidden waste' (an apparent environmental friendly solution that instead presents a great or dangerous amount of waste in some phases of the life cycle), economic problems etcetera. Maxwell et al. [27] argue that every new product concept must be assessed evaluating both positive and negative environmental and social impacts. Even PSS solutions, considered in theory more environmentally sound, must be assess because the sustainability impact can be negative as well as positive.

Summarizing the results drawn by our analysis, we can argue that a sustainable innovative method should be:

- utilized in the early stages of the product development process;
- easy to visualize and use and not time consuming;
- observing the market to understand the expectations of the customer in order to drive the innovation;
- giving constraints in order to inspire new ideas;
- helping the innovation process in three different paths: changing the business model, changing the technology/structure and changing the customer's behaviour;
- assessing and valuate the solutions from a sustainable and economical perspective.

4.3 Eco-tools evaluation and need of a new method for sustainability

After the discussion and formalization of the characteristics of a method for sustainability, an evaluation of the current Eco-tools can be done.

Table 1 Eco-tools evaluation.

	Characteristics						
Tools	**When in the design phase**	**Complexity/Time requirements**	**Use in the companies**	**Aiding the innovation process**	**Final assessment of solutions**	**Observe products/market**	**Life cycle perspective**
LCA [28]	Late	●	◖		x		x
MIPS [29]	Late	◖	◖		x		
MET [30]	Late	◖	◖	x	x		x
Eco-compass [30]	Early	◖	◖	x	x		
Eco-LiDS Wheel [21]	Early	◖	◖	x	x		x
Cecklists [21]	Early	○	●		x		
Spiderdiagram econcept [21]	Early	○	○	x	x	x	
House of Environmental quality [21]	Early	●	◖		x	x	x
Solid works Sustainability module [31]	Late	○	●		x		x
NOTE: The legend on complexity/time requirements and use in companies columns is: ● high ◖ medium, ○ low. In order to reduce the complexity of the analysis and evaluation, costs of implementation were assumed to have the same trend of complexity/ time requirements.							

Firstly, the evaluation process started to sort the current Eco-tools according to the survey proposed by Knight at al. [9], in order to include only the most used tools. After the sorting phase, the Eco-tools have been evaluated according with three criteria:

- When the tool is used in the design phase (in early or late phases);
- Performance characteristics: the complexity/time requirements to implement the tool (in order to reduce the complexity of the analysis, costs of implementation were assumed to have the same trend of the complexity/time analysis column so they were not included);

- The purposes listed in the paragraph above: ‘x’ in the table means that the Eco-tool was created to fulfil that particular purpose;

Data are collected and re-organized from the literature. The Eco-tools evaluation is presented in *Table 1*. Analyzing the table some interesting conclusions can be drawn. Not all the Eco-tools are used in the early stages of the product development process, when is extremely important to take the right decisions in order to minimize the total environmental impact of the product.
Many tools were experienced by the companies as too complicated and time consuming (an LCA analysis, for instance, could take even weeks).
In addition, just some of the tools were created to aid the innovation process, even if not always in the three paths of innovation argued in paragraph 4.2 and showed by the ‘innovation box’ in Figure 1. Furthermore, a very few of them analyze the customer before taking decisions towards sustainability.
By this conclusions it appears necessary to develop a new ‘easy-to-use’ method for sustainability based on the characteristics previously exposed.

5 SUSTAINABILITY INNOVATION WORKSHOP

We decided to build a system of symbols and colors to structure the method, and explain the type of exercise, and in which phase the tool should be used. The tools for the workshop consist of different types of material:

1. *Handbook for the facilitator* (one A4 page) containing the overall structure of the SIW, the systems of colors and symbols, aims and purposes.
2. *Set of cards* (for the facilitator) explaining every phase, tools to use and time to perform each exercise.
3. *Set of facilitation posters* (for the team) containing the exercises and examples to perform the workshop
4. *Set of templates* (for the team) to write and sketch the result of the workshop

5.1 Overall structure

Sustainable Innovation Workshop is a seven steps procedure, see Table 2. Each phase has dedicated exercises for understanding, voting and solving problems. Each phase is distinguished by a symbol and colors labeling system. For details of all phases and exercises see the Master Thesis [12].

5.2 How to perform the SIW

An example is provided in order to clarify how the SIW can be performed, although due to the space constraints of the paper is not possible to explore in detail all the different phases of the workshop. The example tries to highlight some key aspects of the SIW and it focuses on the *Sustainability Triangle*’s exercise and the *Sand Box Play*, the dedicated phases of creativity and ideation.

Example

A shower-manufacturer company is interested how to develop a new product driven by sustainability. With the *point of view* phase, they approach the problem agreeing that building a sustainable product is not only to design it more environmentally sound, but even that it has to fulfill everybody’s expectations everywhere in the world (social part of sustainability) as well as increasing profitability for the company (reaching new market opportunities). During the first phases (*Customer templates*), the product development team explores the customer’s behavior, understanding that there are many kind of behavior, from customers with a more sustainability friendly behavior (5 minutes of shower) to customers that do not think about environmental issues (takes a 30 minutes hot shower because the cost of clean water and heating is very low compared to the satisfaction of the hot shower). After these phases, the team divides in two groups and they perform the *sustainability triangles exercise.*

Table 2 SIW overall structure

Symbol	Name	Type	Exercises	Converging/ Diverging	Outcome
	Point of view	Focus	Why?, Where?, What?	Converging	Agreement of the problem area
			Tag line	Converging	An agreed topic
	Customer Templates	Explore	Customer's quotes	Diverging	Brainstorming about customers behaviors and expectations
			Creating personas	Converging	A shared understanding of the customer expectations
	Choose one quote	Selection		Converging	Choice of one quote/persona to explore more in detail
	Sustainability challenges	Result	Sustainability triangles	Diverging	Set of challenges for the team
			Bumper car sticker	Converging	Formalization of the challenges
	Sand box play	Concepts	Roles templates	Diverging	Set of concepts
	Choose one concept	Selection	Camel/horses ranking	Converging	Ranking of the concept (risk and opportunity) and decision about future direction
	Analyzing the idea	Explore	'Hidden waste', Waste management, Back to future	Diverging	Analysis of the chosen concept and weak spots of the current solution
			Recording	Converging	Set of issues to develop and improve

SIW in detail- Sustainability Triangles exercise

The purpose of this exercise is to create a challenge for the team in order to drive the innovation process. The tool is developed to explore three different dimensions of sustainability. In the exercise the team members have to discuss, decide and write their challenges for solving the problem in three different aspects. These are:

1. *Change customer behavior*, how the team wants to change the customer's behavior with the design,
2. *Environmental requirements*, which environmental constraints it wants to fulfill,
3. *USP*, which kinds of market advantage the company wants to attain from the solution.

The results of the exercise are shown in Figure 2.

- *Triangle A* (dotted line): the group decides to find a solution in which there is no change in the customer behavior, that fulfill an environmental requirement in the team (i.e to save 30% of the water used per minute), and to have a small advantage compared to the competitors.
- *Triangle B* (continuous line): the group decide to find a solution in which there is no change in the customer behavior, that fulfill the Earth's requirements about water (i.e do not waste any drop of water) and to have a unique product (compared to other competitors).

After deciding the challenge, the two groups are ready to pass through the pure creation phase, called *Sand Box Play*.

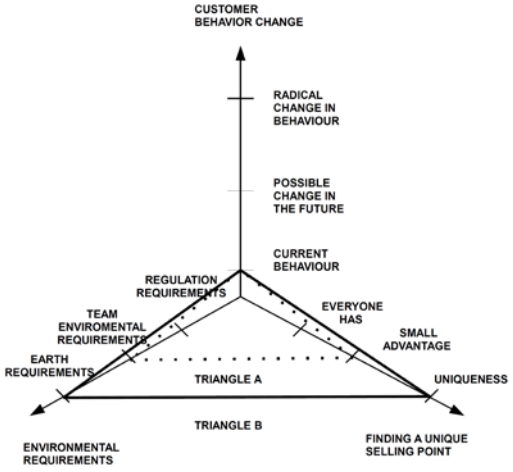

Figure 2 Sustainability triangles exercise

SIW in detail- Sand Box Play

This exercise is expressly designed to help the team to come up with new ideas. In order to explore different solutions, in this phase the team members have to create a solution playing roles. Every role explores a different aspect of the innovation process. These roles are:

1. *Scientist,* that has to solve the problem changing the technology/ structure;
2. *Anthropologist,* that has to solve the problem changing the customer's behavior (i.e with rewards or penalties based on a different behavior);
3. *Business man,* that has to solve the problem changing the business model (i.e exploring new solutions as PSS).

For every role are provided the appropriate template (to write and sketch the solution) and a badge. It contains the *ideas' evolution path,* a set of guidelines and examples in order to help the user to build his solution.

In order to reduce the complexity of our example, we suppose that every group uses just the *scientist* role, so the solution will focus only on the technology and structure of the shower.

The two groups start to work separately using the *Sand box play*, after the phase each group presents a concept:

- Group A product concept: shower with water conserving devices (restricts the flow of water),
- Group B product concept: 'one loop shower' concept, the water is collected after the use, filtered and then returns in loop with an electric pump.

The workshop continues starting to rank the two ideas (*choose one concept*) and deciding to continue with the second concept, arguing that this solution is more environmentally sound (huge decreasing of water consumption) and, respecting what stated in the first step, more socially sound.

After this step the team continues through the last phase (*analyzing the idea*) valuating if the solution presents some weak spots from a sustainable point of view. From the analysis emerges the problem of the 'hidden waste' of electricity connected to the use of the electric pump (that is not needed in the concept A). The meeting concludes and decides to continue with the second concept, and focus in the next meeting focus on the electric pump.

6 EVALUATION

The method presented is a result of iterative testing (in courses both at advanced and graduate level), evaluation and redesign during six months at Luleå University of Technology. From each workshop, test data were collected (through video recording in the design observatory, reflections from the users, and the documentation from the workshop) to find and improve the weak areas, treating the method as a product concept itself. An overall experience was that each exercise has to be very focused, where earlier versions of the method tried to combine several steps into one exercise. One exercise that gained many positive responses from the users was the sandbox play exercise, which was used instead of classical brainstorming. The team also appreciated using quotes in the 'customer templates' exercise, and found it easier to use than the traditional way of creating personas.

In section 4.2 the characteristics for a method for sustainability was identified and formalized. As well as with the other Eco-tools, is important to evaluate the SIW according to these characteristics.

- **utilized in the early stages of the product development process:** the SIW is designed to be used in the very early stages of the product development process in order to drive innovative solutions by sustainability concerns;
- **easy to use and not time and cost expensive:** all the tools of the SIW are quite inexpensive (only posters, posts-its and stickers are necessary) and are relatively quick to perform (it requires around half of a working day);
- **observing the market to understand the expectations of the customer in order to drive the innovation:** in the first stages of the SIW the *customer templates* exercise analyze the customer with the use of quotes, which then are used in the rest of the process;
- **creating constraints to challenge the team for achieving radical innovation,** with the 'sustainability triangles' exercise the team creates the constraints that drives the innovation process;
- **helping the innovation process in three different paths: changing the business model, changing the technology/structure and changing the customer's behaviour:** the *sand box play* exercise is designed to explore the problem from different perspectives and it helps to find solutions in the three paths already cited;
- **assessing and valuate the solutions from a life cycle perspective:** the latest exercises in the workshop, such as the 'hidden waste' or 'back to future' is used to analyse the solution finding out possible cases of 'hidden waste', cost of implementation problems etcetera.

7 CONCLUSIONS AND FUTURE WORK

In this paper, a new method for sustainability (Sustainability Innovation Workshop-SIW) is presented. Before the developing the method, a literature research was performed where weak areas of existing methods for sustainability were exposed. The main conclusion was that there is a need for an easy-to-use method to incorporate sustainability aspects during the very early phases of the product development process. Although the decisions made during these early phases determine almost all the future environmental impact of our product, no detail design is done at this stage. Hence, it is difficult to use an analytical and precise method, such as LCA analysis, due to the lack of quantitative data.

Furthermore, there is a necessity to implement easy-to-use methods in organizations, such as small companies, municipalities and non-profit organizations that might not have the expertise and the resources to implement expensive and detailed software-based eco-tools.

The characteristics of a method for sustainability were discussed and formalized after the literature analysis, and they framed the development of the SIW. The method has been evaluated and redesigned over a six-months period of tests in advanced and graduate courses at Luleå University of Technology. A final evaluation shows that the method presents all the characteristics presented.

The initial tests show promising results, but further evaluation must be done before any general conclusions can be drawn. Future work will include tests in different types of organizations.

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