

Design Process and Sustainability. Method and Tools

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Abstract: The sustainable design approach has so far particularly referred to methods and tools of an analytical nature, such as Life Cycle Design and Life Cycle Assessment; these are characterized by the direct focus on product and/or service and defined by prevalence of a convergent thought. The project has to deal, by its nature, with complex issues defined as wicked problems that cannot be circumscribed and then linearly resolved; the design act is indeed characterized by being a complex dynamic and not definable in a rational way. The paper identifies methods and tools applied to the POR CreO-FP7 “High Chest” project developed with Whirlpool Europe S.r.l. The design process applied has been then re-created highlighting methods, tools and their areas of relation, which, in Complexity theory, are defined as edge of chaos: these are the areas where the different theories and disciplines do not repel but attract, changing from order to disorder, which consequently leads to organization through interrelationships.

Keywords: Design Process, Sustainability, Method and Tools, Product Design, Complexity

1. Introduction

The limitations of the current development model (Meadows D.H. et al., 2004) indicate that it is not possible to carry on any design activity without setting it on a level with all the relations that the product will have with the environment and the cultural, social, economic, productive and technological aspects. Maldonado T. (1991) had previously stated that the design task is designing the shape of products by coordinating, integrating and structuring an extremely heterogeneous number of factors (functional, symbolic, cultural, techno-economic, techno-constructive, techno-systemic, techno-productive, techno-distributive).

The approach to complexity is grounded in the theories on the project proposed by Simon H.A. (1969 ed. 1988), who sustained the application of a limited rationality in the design field, and Schön D.A. (1983), which considered the project as a reflective practice, thus defining the epistemology of practice theory (Bertola P. et al., 2004). The design project has to deal with a complex system of extremely heterogeneous domains, therefore it cannot be resolved through reductionism and linear approaches. Simon H.A. (1969 ed. 1988, p. 156) had previously revealed that in the real world design procedures should not be limited to assembling the solutions of the individual components, but should seek the appropriate aggregation of the components by applying the concept of "placing eggs in different baskets".

Design has often to deal with what are termed “wicked problems” (Buchanan, 1992) characterized by a no definitive formulation; no stopping rules; neither true nor false solutions (only good or bad); not

being solved by an exhaustive list of eligible operations; having more solutions; bringing after their resolution another problem at the highest level; not having a final verification; being unique; not reproducible solutions. This is why by applying too specific tools there is a risk of having a restricted view of the design problem and therefore of applying a solution that is strictly limited to the re-design of a product.

Sustainability-oriented design mostly develops for environment-related issues and more specifically toward the product intended as a tangible object. With the association of the words 'Design' and 'Sustainability' frequent reference was made to the re-design of a product, by applying a design approach based on a change of material and without affecting functionality and meaning.

By that, in some instances, it had been assumed that certain analytical methods and tools, such as Life Cycle Design (Vezzoli C. and E. Manzini, 2007 p. 66) or Life Cycle Assessment (Baldo G.L. et al., 2008 p. 61), could be tools for guidance for designing sustainable products.

This is not to mean that these tools are not important, but that this kind of approach has led to tag all products made of sustainable materials with an eco-design label. Basically, the tendency has been that of "adjectifying" design coming to an incorrect interpretation of what is the design and that of which should deal. Lawson B. (1980 ed. 2005) too points out that the word "design" is the first problem, often used as an adjective rather than a noun and should be used as a design process and a way of thinking instead.

Tools that are too specific lead to consider only certain factors at design stage, leaving aside many other perhaps even more important. Proof of this are energy labels applied to household appliances, which communicate the energy class of the product through symbols and letters. If it is true that a refrigerator with A+++ energy label is more efficient in terms of energy consumption to a lower energy class refrigerator, it is just as true that the use and management of a double-door A+++ refrigerator has a larger impact than a simple single-door A+ model. As highlighted by the European Commission consumers are nowadays inclined to buy larger products (European Commission, 2015) that belong to a higher energy class but have higher consumption.

Issues related to sustainability do not only concern energy consumption and we can not approach the design of a product working on a single aspect. If our model of consumption leads us to buy a larger model of refrigerator to accumulate food, due to the little time available because of an overly long working time or to own that product in order to belong to a specific social status, it is clear that the issues are also of social and cultural order.

For a real sustainability revolution a cultural change is required (Ehrenfeld J., 2008); the contemporary scenario leads us to face a number of challenges regarding the imbalance of various interacting systems: energy, climate, food, money, culture (Thackara J., 2005).

In a world of limited resources, it becomes necessary conceiving and approaching to a different kind of growth (Capra F. et al., 2014) which is not only economic, material and quantitative; the goal is to understand the qualities of the complex system we live in, not as a mere sum of its parts but as a complex interrelationships system, where qualities derive from relationships and interrelationships among the components of the system itself (Capra F., 2013).

In this context, it is not possible to separately face design issues; that is why a more complex interdisciplinary and transdisciplinary approach is needed. Complexity, as argued by Morin E. (1985, p. 57), is solved with a multi-dimensional and dialogic thinking. Therefore also in the design field, where the necessity is to connect different domains of knowledge, a divergent approach is needed, thus avoiding the fragmentation of the single problem.

In the project area, the quantitative and analytical approach by which to now has been addressed sustainability issue, opens out to assessments and approaches of a qualitative nature that better address the design hypotheses towards overall and future scenarios (Tamborrini P., in Vezzoli C. 2007), thus expanding the horizon of the project to lifestyles and life quality. More generally, this

way of looking at sustainable design complexifies the act of design and bringing the designer to be a strategist in the identification of new relationships between all parties; it is then defined the strategic design for environmental sustainability concept (Manzini E. et al., 2001) (Vezzoli C. et al., 2007). The Strategic Design for Environmental Sustainability moves the competences from product design to the design of an integrated product and service system that meet the specific needs of the customer, attempting to reorient the production and the consumption in a sustainable perspective. Within the disciplinary framework, with Product Service System (Ceschin F., 2012) (Vezzoli C. et al., 2014) and Design System (Bistagnino L., 2008), the design issues about sustainability have then moved from an attention over matter - that is the object of environmental damage - to an attention to the shape - meant as the layout drawing of the system. The tension between form and matter:

“[...] is a tension that lies between two different approaches in a way to understand the nature [...] The study of matter originates with the question: 'What is it made of?'. It leads to the concepts of fundamental elements, building blocks; to the measurement and the quantification. The study of the form asks: 'What is the pattern?'. And that leads instead to the concepts of order, organization, relationship” (Capra F., in Bistagnino L., 2012, p. 207)*.

**Translated by the author.*

Conceiving the project becomes essential in design area, by considering all the interrelationships that a product, a service or system generates with the environment and social, cultural and technological aspects. The transition from the focus on the product in the physical object horizon, according to Findeli A. (2001), leads to the "disappearance" of the object as the center of the project, focusing the design process on all the system parties, therefore going to cancel the concept of "commodity fetishism" and consequently bringing the design act to a more ethical approach.

The complexity facing a design project must be approached in order not to allow the analysis to become the dominant or exclusive rational thinking process (Nelson H.G., Stolterman E., 2003); therefore it becomes necessary a redefinition of methods and tools, and more broadly of the approaches used in the sustainability oriented design.

The concept of design practice regains value in this sense too, by expanding concepts and capabilities belonging to design as the system thinking (Zurlo, 2014), that is the ability of design to act strategically in the complex system of systems.

1.1 Which methods and tools?

When talking about sustainability-oriented design, it is quite consolidated the fact that designers can play an important role especially in the early stages of design (Lofthouse V., 2004 and 2006) (Vezzoli C., E. Manzini, 2007) where the 80% of impacts has been determined (Thackara, 2005). As evidenced by several authors (V. Lofthouse, 2004) (T. Marttila, Kohtala C., in Vezzoli C. et al. 2014, p. 451) it is not quite clear which tools and design approach should be taken into consideration.

In the above context, the whole design flow and the related methods and tools acquire relevance, from the most specific tools as LCD and LCA to those of a general nature specific to the design practice. To foster a divergent process, which is specific to the design practice, it is necessary to ensure that the methods and tools used during the design flow are extremely heterogeneous and at the same time geared to produce the same result by sharing objectives, practices and skills.

Traditional tools such as Life Cycle Design are qualitative, but still directed to the material aspects; Life Cycle Assessment has a quantitative and engineering matrix, but is of little use to the practice of a designer (Vezzoli C., E. Manzini, 2007) and restrictive with regard to the innovative potential of a project (D. Millet et al, 2005). Both tools are too restricted in front of the complex issues related to sustainability and to the nature of the project itself.

It is of interest investigating how methods and tools of different nature encourage the project fertilization in connection to the same design flow, in order to identify possible areas of relationship and then detect new methods and tools.

For example, the Design Thinking formalized by IDEO (2015) through a number of methods and tools, and drawing its roots by thoughts concerning the methodologies related to the design to Simon H.A. (1969, ed. 1988), D. A. Schön (1983) and Buchanan (1992), has been identified as a promising process to address the challenges about sustainability (Young G., 2010) (Fischer M., 2015) and meet the challenges of innovation for complex systems (Johansson-Sköldberg U. et al., 2013).

The paper investigates, through the practical application in a research project, about how some heterogeneous (quantitative, qualitative and practical) methods and tools encourage the project fertilization. More specifically, design methods and tools specific to Environmental Sustainability (LCD and LCA), the Design Thinking (brainstorming, moodboard, workshops), Ergonomics and the User-Centred Design have been applied, besides the traditional design tools (from design sketches to 2D and 3D rendering softwares).

1.2 Paper sections

The paper is divided in three sections:

1. In the first section (2. Methods and Tools applied in High Chest project) the methods and tools used in the different project stages are reported in detail;
2. The second section (3. Main Results) highlights the main results provided by methods and tools applied; in the second part of this section, used methods and tools are positioned in the design flow and are divided into four macro categories, thus going to understand at which stage in the project they have contributed to its fertilization;
3. The last section (4. Discussion) carries out a discussion concerning relationships arising between the different methods and tools throughout the design process.

2 Methods and Tools applied in High Chest project

The aim of the POR CreO-FP7 “High Chest” project developed with Whirlpool Europe S.r.l. was to design a new family of chest freezers that would be innovative in terms of environmental sustainability, energy efficiency and the promotion of eco-efficient behaviours guided by good design.

The DIDA* Department research group - University of Florence - has been working on three levels:

- A. sustainability: expert assessment according to the principles of Life Cycle Design, Life Cycle Assessment of the existing product and of the innovative concept product (comparative analysis);
- B. ergonomics: expert evaluation and users testing moving from the theoretical and methodological bases of User-Centered Design (UCD);
- C. product design and interface: with a particular focus on shape innovation and on usability in terms of fuel savings and reduction of waste related to food.

Workshops with students have been held during the research project under the coordination of researchers and some tools of Design Thinking (IDEO, 2015), as brainstorming and moodboards, have been applied.

2.1 Project phases: Methods and Tools

The project can be divided into four macro phases.

FIRST PHASE

In the first phase expert evaluations have been conducted in relation to the existing freezer manufactured by Whirlpool. A visit to the company has preceded the expert assessments; it has allowed the group to identify the existing freezer model to conduct analyzes and assessments.

From the ergonomics point of view critical issues have been identified through direct observation and following Task Analysis (G. Lotti, Tosi F., Brischetto A., I. Bruni, 2015) at the LEU/Laboratory of Ergonomy and Usability (DIDALABS, Department of Architecture, University of Florence, Italy). In terms of environmental sustainability, with reference to the BOM of the product, an analysis of the critical issues relating to materials applied through the use of Matrec database used at the LDS/Laboratory of Design for Sustainability (DIDALABS, Department of Architecture, University of Florence, Italy) was conducted. As it regards the technological and formal innovation a benchmark analysis has been carried out to investigate the competitors also in similar sectors.

SECOND PHASE

In the second phase, for the aspects linked to usability and ergonomics, sessions have been conducted by providing the involvement of users with different anthropometric features, approximately belonging to the 5th, 50th and 95th percentiles.

“The sessions were attended by a total of 11 persons, 6 men and 5 women aged between 35 and 75 years. The sessions were held in the company premises, in an area in which the typical domestic conditions of use of the chest freezer were recreated. The users were involved in the experimentation of a hybrid method of investigation, simultaneously developing Contextual Inquiry, Observation and Thinking Aloud and following a heuristic approach. This approach made it possible to collect opinions, thoughts, expectations, criticalities and intuitions useful for the definition of the requisites of the design concept” (Lotti G., Tosi F., Brischetto A., Bruni I., 2015).

As it regards environmental sustainability it was rather conducted a simplified LCA relating to the previous Whirlpool freezer model, with particular attention to the phases of pre-production, product manufacturing and packaging. The analysis was conducted through a simplified tool provided by Matrec Ltd. and supplied by LDS. The analysis has led to a result in terms of environmental impact of the existing product that has later allowed the identification of some intervention areas for the design of the new High Chest product.

THIRD PHASE

The third phase included a workshop coordinated by the whole research group; 15 students of the Course Master's Degree in Design - Department of Architecture, University of Florence - have been involved. The workshop took 5 days of intensive work in order to generate product concepts based on the analyzes carried out previously. During the workshop methods and tools of a different nature were used: from brainstorming to the moodboard to get to the material DB always having as a reference the principles of Life Cycle Design. At the

end of the workshop three projects have been selected, and the students/designers have subsequently worked with the research team to synthesize the final design.

STEP FOUR

The fourth and final phase involved the design synthesis of the three selected concepts, both as regards the product and the functional and graphic aspect relating to the interface. Tools of 2D and 3D design software (Illustrator, Rhinoceros, 3DSmax) have been used . A simplified LCA was also conducted in the last stage, performed with the same approach of the aforementioned LCA, in order to compare the impacts of the old model with the new High Chest design concept (Figure 1).

Finally, a manual of the project has been drawn up and the new model of freezer has been presented, together with all the designs arising from the workshop, during a conference organized at the Design Campus in Calenzano (FI) - Department of Architecture, University of Florence - Italy.



Figure 1. Concept High Chest

3. Main Results

The methods and tools applied in the High Chest project belong to different scientific disciplinary sectors and include different design approaches. All methods and tools used have at least contributed to the development of the project towards sustainability.

The expert assessments related to ergonomics have been used for the definition of a Task Analysis used as a design basis for students during the workshop; the same applies to the environmental

assessment carried out in the first stage of the project and useful to identify hypothetical materials with reduced environmental impact and applicable in the new concept.

The subsequent analysis performed using the UCD methods allowed to obtain information about the user-product interactions and define the needs of users in relation to the context of use (Lotti G., Tosi F., Brischetto A., Bruni I., 2015). Analysis revealed that users perceive the low level of aesthetic and functional innovation in this type of product is often relegated to hidden areas of the home or even in garages and basements. The most significant problems emerged from tests with users concerned the handle, too small for a easy opening, the size of the product that do not facilitate the use by the users belonging from 5% to 50% percentile and the internal organization of the chest that does not facilitate the storage of food (Lotti G., Tosi F., Brischetto A., Bruni I., 2015). In conclusion the design choices made for the new model's design involved a more easy accessibility to the product and the introduction of an interface to facilitate the management of food and reduce waste (Figures 2-3).



Figure 2. The picture shows the interface configured for High Chest freezer. The interface is designed to guide the user through the filling operations and withdrawal of the product. The interface also enables monitoring and management of the overall device status, the status of the stock zones, the status of food expiration, It also suggests recipes with products which are expiring in order to minimize food waste. The interface leads to minimize the chest's openings with a decrease of cold leakage, thus favoring a reduction in consumption. The interface technology was developed by the Institute of Biorobotics - Scuola Superiore Sant'Anna.

The simplified Life Cycle Assessment conducted on the existing product has allowed the research to identify the most impactful components in terms of KgCO₂eq emissions and kWh consumption. The external sheet, also being the major component, had the more impactful result but it was also difficult to replace because of the conductive capacity of the metal which facilitate a correct distribution of the cold. In the new model, it has been slightly reduced the thickness of this component, in order to decrease the weight and therefore the impacts.

The analysis also allowed the assessment of alternative materials with regard to the insulation material, the main polymeric components and packaging materials.

Polyurethane foams from renewable sources were evaluated for the insulating material, while recycled PET for plastic materials and recycled EPS for packaging.

The workshop allowed students to experience some methods and tools related to the practice of Design Thinking (IDEO 2015) as brainstorming and mood boards and methods and tools related to Life Cycle Design.

Here it is shown the difficulty of students into apply the principles of the LCD directly to an existing product without first freely conceiving and designing products through closer methods closer to the design practice (sketching and personal reflections based on the analysis provided by the research team). The Life Cycle Design is more easily accepted by the students when used in parallel with the online Matrec DB¹. In this phase traditional methods and tools have been used, as sketches in the very first stages of conception and of 2D and 3D rendering software in the final representation phase. In the final design phase methods close to the design practice have been used to refine the formal and functional aspects of the product. 3D modeling tools and rendering have been used in particular. To determine the technical aspects and the size was used a CAD software instead. In the final part of the project, the comparative simplified LCA on High Chest concept, has led to an impact reduction of approximately 12% in terms of Kg/Co2 eq emissions and the KWh consumption for pre-production and production steps.



Figure 3. The interior color of the chest baskets facilitates storage and food handling

3.1 Method, Tools and Design Process

The methods and tools used in the research project are grouped into four major categories:

1. Visualization Methods and Tools;
2. Quantitatively Measuring Methods and Tools;
3. Thinking/ Seeing/ Predicting/ Methods and Tools;
4. Evaluate Qualitatively Methods and Tools.

1 <http://www.matrec.com>

The naming of macro-areas has been inspired by Zurlo F. concepts (Zurlo F., 2014) which are related to the designers' skills: "seeing", "pre-seeing" and "far-seeing".

According to the author, the abilities related to "seeing" skills feed on the concept of zooming and allow designers to drift away and getting closer to problems; the abilities related to "pre-seeing" refer to a critical anticipation attitude related to possible future scenarios; finally the concept concerning "far-seeing" refers to the designer's ability to summarize through an image the meaning of a project.

On account of this, the identified categories (Visualization Methods and Tools and Thinking/ Seeing/ Predicting/ Methods and Tools) include practical methods and tools belonging to the early design methodological definitions, such as brainstorming (Jones J.C., 1970, ed. 1992); the other two categories (Quantitatively Measuring Methods and Tools and Evaluate Qualitatively Methods and Tools) include instead analytical methods and tools of analytic and specific nature about certain disciplinary areas.

Subsequently, the methods and tools used have been included in a hypothetical image related to the design process and shown by Newman D. (2008), called Design Squiggle (Figure 4), which does nothing more than refer to the concept of "macro-structure" proposed by Bonsiepe G. (1975, ed. 1993).

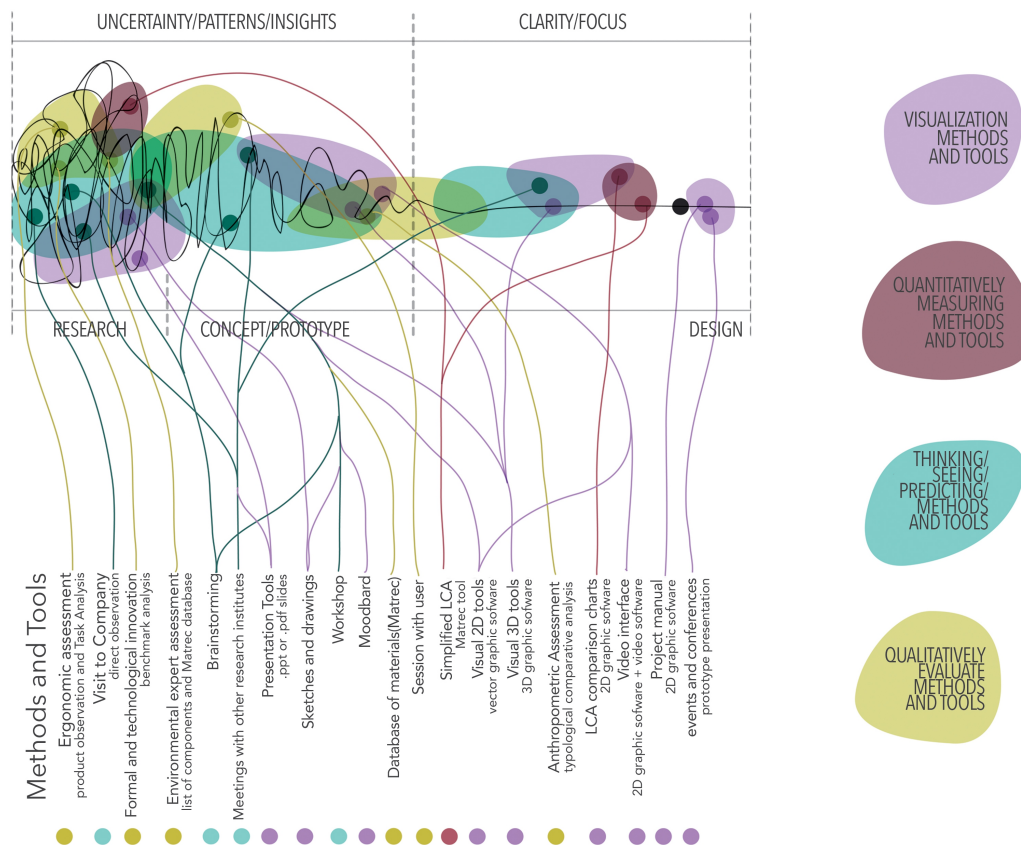


Figure 4. Tools and method project High Chest

4. Discussion

To face the challenges of sustainability in the broad sense it becomes necessary to make an act of design that have a significant effect on consumption patterns and lifestyles.

The paper points out that it is not possible to design through the use of too specific tools such as the LCD and LCA; these should be interrelated with other typologies of approach taking into consideration all the design process. The design process, especially in early stages, should allow a

type of divergent thinking aimed to the identification and possible resolution of so-called Wicked Problem (Buchanan, 1992); as can be seen from the design flow, there is a broader application of methods and tools in the very early stages of design, which are closer to the design practice than analytical methods and tools.

The methods and tools applied during the research project are extremely heterogeneous and belonging to different disciplines but still all oriented and used to produce the same effect.

The methods and tools divided into the four macro categories proposed in the previous paragraph, and placed in the graphic representation of the design process, identify potential areas of relationship between heterogeneous tools. Then it can be assumed that each macro area of action influences the other in a continuous exchange of interactions and knowledge and the design process therefore takes on highly complex shapes where the boundaries of individual areas do not divide the methods and tools but rather put them in relation to each other by generating some form of organization.

As recalled by E. Morin (1977) each boundary, as well as barrier is a place of exchange. In this way it can be defined the various areas that overlap like the points of Edge Effect (Thackara J., 2005), a concept closely linked to the theories of complexity and more specifically to the theory of the edges of chaos or border areas.

“We are used to thinking to the order, and we are used to think of the disorder. But we are not used to think to the order and disorder together. [...] Natural systems are in a situation of dynamic order, which is neither the immutable and static order, nor the uncontrollable and potentially dangerous disorder of chaos”(De Toni A. F., 2013)*.

*Translated by the author.

Natural systems generate themselves in a continuous exchange of relationships among the various system components, keeping it in balance (Capra F. in Pisani F. 2007).

By analogy, the areas represented on the design process (Figure 4) allow individual tools to move in the limits of boundaries, therefore going to establish contacts with other methods and tools, creating and re-creating, thus the same flow of the project.

The project, in the complexity of the systems and issues that it faces (environmental, social, cultural), is a dynamic thriving at the edge of chaos, in the connections between the various disciplinary fields, in the dialogue between different instruments and the same parties involved in the project.

It is a dynamic continuously redefining until the achieving of a balance. This balance, which in the design field can be referred to the output of the flow and then at the end of the squiggle, however, generates a new beginning because the design in his reflective practice (D.A. Schön, 1983) feeds theory and vice versa in a continuous exchange of knowledge.

5. Conclusion

The paper investigates how, through a practical application in a research project, some heterogeneous methods and tools (quantitative, qualitative, practical) favor the project fertilization. The design originated by the High-Chest project shows that the results related to sustainability were not only achieved through the application of analytical methods and tools, but also with those closer to the design practice.

The mapping of the design process (Figure 4) shows hypothetical connections between heterogeneous methods and tools, in order to develop in the future methods and tools that connect different disciplinary areas and different design approaches, thus allowing to design in the complexity where the act of designing takes place.

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