Design for Sustainability: A Review

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Abstract: *Sustainability is topic of great concern since the last decade and still today does not lose of its popularity. Reason for that is that the contemporary way of living is causing great damages to the environment. Designers have been talking about changing the ways in which the products are designed in order to have sustainable product. But, for achieving sustainability many aspects need to be addressed, such as: cultural, social, economical and technological. Nowadays, we believe that these aspects are on higher level and we can talk about sustainable design.*

Every product development process starts with the design phase and this is why we believe that it is most important for making improvements of the products. In this paper we have the premise that good and appropriate design can have positive influence on the sustainability. In order to check the validity of the premise we are reviewing paper dealing with sustainability, eco design, and engineering materials.

Keywords*: DESIGN PROCESS, SUSTAINABILITY, CIRCULAR ECONOMY*

1. Introduction

Since the of the time homo sapience's humans depended on the nature, and therefore cared for it and nurture it. However, with the industrialization and globalization humans have been obsessed with satisfying their needs. Satisfying those needs meant cutting down forest, endangering lives of hundreds if not millions species (animals, birds, fish, and plants), causing climate change and what not. Human activity has even been connected to a global "sixth mass extinction" of animal species and "massive anthropogenic erosion of biodiversity and of the ecosystem services essential to civilization" [1].

Over the years many different terms have been in circulation. Earliest are green design and then eco design, referring to ecofriendly design of products, meaning that in the design phase the designer takes care of minimizing the negative effects on the nature throughout the whole lifecycle of the product.

In the later years terms such as sustainable design have emerge, taking into account the whole process including the sociological and economic factors. So it can be said that the sustainability stands for much broader aspects, having the UN'S sustainable goals as reference. The concept of sustainable development stands for harmonizing development processes with respect for the environment, in the interest of future generations. Going by an analogy between the processes of natural transformation and those of industry, sustainability concepts take inspiration from nature's teachings in an attempt to optimize the flows of resources that characterize the entire industrial system and the life cycle of products [2].

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3]. With this definition of sustainable development, in 1987 the World Commission on Environment and Development (WCED) outlined what is now widely recognized as the guiding objective of the current process of economic and technological development - to ensure that the use of environmental resources to satisfy present demands are managed in such a way that they are not left so damaged or impoverished that they cannot be used by future generations. After more than 30 years since the publication, it now seems that a complete vision of the problem has finally matured, where sustainable development is considered a process that includes all three key factors: **economic, sociocultural and environmental** [4]. It is important to stress that the science and the technology are in direct connection to every one of the key factors and are expected to provide data and tools for achieving balance [5] which is the necessary for sustainable development.

In order produce eco products or products that are ecofriendly the industry has to adapt as well. This is the beginning of industrial ecology (IE) which has to provide better understanding and application of the system necessary for achieving sustainability [6]. According to scholars [7; 8; 9] working in this discipline in order to obtain sustainability the industrial ecosystem must be closed cycle same as the biological ecosystems. In the recent years the term circular design has been in use, the term which clearly stands for achieving a closed loop of the product's life cycle. Throughout the years the IE slowly transitioned into circular economy (CE). The field of IE provided the foundations for the idea of a CE [10; 11; 12]. Building on original IE thinking [13; 14; 15] the CE has recently been (re-)popularized as both a public policy and business concept [16; 17]. Developed countries [18; 19; 20] are trying to adopt CE principles as guidelines for the envisioned redesign of their economies [12], which requires changes on the macro-level (cities, provinces, regions, and nations), meso-level (networks, eco-industrial parks), and micro-level (individual companies, consumers) [11].

We believe that the design has crucial role in achieving sustainable development or CE. In this paper, we are reviewing different sources on eco design, sustainability and circular economy in order to comprehend the influence that the design process has in each of these disciplines.

2. State of the art

Eco design can be considered as a part of the sustainable product design. It is a well-known discipline that provides designers with design methodologies, eco design strategies, methods and principles helping them and guiding them into the design process of or creating products that do not have large negative implication on the environment throughout the whole life cycle [21; 22; 23; 24; 25]. But the countries and so the companies are slowly shifting towards the circular economy (CE), which requires different approach when designing. Designers are lacking methodologies and strategies to guide them through circular product design when designing for the circular economy [26]. den Hollander and colleagues [27] in their research focus on creating methodology for circular product design, focusing of product integrity, which they believe is the key to no waste policy of the CE. The authors' propose a typology of three stages for product integrity: long use, extended use and recovery. Design approaches for long use are method of resisting the obsolescence, which encompasses: design for physical durability and design for emotional durability [28]. Design approaches for extended use are in fact postponing obsolescence and those are design for maintenance and design for upgrading. Design approaches for recovery are: design for decontextualizing, design for repair, design for refurbishment, and design for remanufacture, aimed at reversing the obsolescence [27].

Emotional durability researched by Page [28] is something that is rarely being discussed and researched. But that is not because it is not important but because is complex area requiring large subject sample in order to make objective conclusion. She conducts a literature review from which can be concluded that emotional durability and product attachment are influenced by different

factors. These factors can be used by the designer in order to design products that are more desirable and harder to toss away.

CE is slowly becoming something that the societies are striving upon, and the main goal of the CE is zero waste. This is why many researchers work on proposing different strategies and methodology that provide no waste.

The CE may be defined as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, and repair, reuse, remanufacturing, refurbishing, and recycling" [29].

In this age of extensive consumeristic human behavior, massive amount of waste are produced every day. One area of high number of waste is the garment industry, since the production is high and at the same time the styles are changing very fast. Achieving zero waste in the industry requires major changes in the production processes which is long and expensive task. No waste would mean that there should be 100% resource use in the production. Along with the changes in the production process, also there should be changes in the aesthetic/fit of the contemporary designs [30]. As their contribution to the CE, Kääriäinen and Niinimäki [31] conduct material research in order to create sustainable textile materials. The empirical basis of this study consists of five material research and development projects. They investigate the projects to understand not only the approaches to producing sustainable textile materials, but also to map the differences in the scientific dialogues.

On the other hand numerous authors critique the waste hierarchy. Behrens and colleagues [32] critique it for having a positive impact on dematerialization and decoupling, given that it focuses only on waste and does not address material inputs directly, nor consider economic output. Van Ewijk and Stegemann [33], provides a critique relating to the hierarchy's priority orders. First, they argue, inclusion of an option in a priority order legitimizes its existence (i.e., disposal). Second, the common understanding is that one needs to move up the hierarchy rather than necessarily achieve the highest outcome. It is about the direction of change rather than the end goal, which illustrates the relative nature of the waste hierarchy. McDonough and Braungart [34] refer to the waste hierarchy as the logic of death and argued that solution should be made to design for abundance. Their argument is that growth isn't in and of itself wrong, only the way we do it and that the things society and industry tends to want to grow like product sales and dividends – unless also tethered to the finite environmental (and social) limits of our planet – are the very things that can make abundance for all impossible to achieve.

3. Discussion

Authors of the review paper have different proposals for achieving sustainability and CE. The difference is that in the sustainable development the goal is to prevent occurrence of waste or to minimize it, where as in the CE there should not be waste. This main difference is the reason for different approaches and proposed methodologies. In the prevention of waste we must think in the design process on how to design products that do not use abundance of natural resources that do not require long and complex production processes, localised manufacturing, optimised transport, fast assembly and possibility for reuse, remanufacture od recycle. In the CE there should not be waste this is why there are just two approaches:

- Design for extending the useful life of a product and
- Design for recycling.

In Design for extending the useful life of a product are approaches for long use (design for durability and design for emotional durability), approaches for extended use (design for maintenance, design for upgrading) and approaches for recovery (design for decontextualizing, design for repair, design for refurbishment, design for remanufacture) [27].

Extended life cycle – ref

The ultimate goal of *design for product integrity* is to minimize and ideally eliminate environmental costs by preserving or restoring the product's added economic value over time. Extended product lifetimes, however, do not always result in a net reduction of environmental load. Over time, newer versions of products may be developed that incorporate more efficient technologies. From that moment on, the environmental impacts that arise from the prolonged use of a product may become larger than the embedded impacts of a more efficient replacement product [35]. Because the Inertia Principle does not account for this, product designers need to understand the ecological consequences of their design interventions.

Design for recycling consists approaches and strategies for waste management and transform it into resources. In order to ensure that, in the design process the appropriate type and amount of material should be selected. The selected material need to be recyclable, but also there should be market demand for it and the recycling process needs to be efficient and economical.

4. Conclusion

Sustainability and CE are important topics for the contemporary society and it is a positive thing that they attract so many researchers.

In this paper we analyzed different research papers with different approaches in the sustainability and CE. But every one of the implied that design phase is the crucial for achieving the goal, whether it is extended life, recyclability or zero waste. This only affirms the premise from the beginning of the paper that the designer is the one that needs to design product that can have extended life or be recycled.

For further research the number of researched paper has to be extended and their categorization according to the specific area of interest should be made.

References

1. Ceballos, Gerardo, Paul R. Ehrlich, and Rodolfo Dirzo. (2017). Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proceedings of the national academy of sciences* 114.30.
2. Giudice, F., La Rosa, G., & Risitano, A. (2006). *Product design for the environment: a life cycle approach*. CRC press.
3. Holden, E., Linnerud, K., & Banister, D. (2014). Sustainable development: Our common future revisited. *Global environmental change*, **26**, 130-139.
4. Robèrt, K. H., Schmidt-Bleek, B., De Larderel, J. A., Basile, G., Jansen, J. L., Kuehr, R., ... & Wackernagel, M. (2002). Strategic sustainable development—selection, design and synergies of applied tools. *J. Clean. Prod*, **10**(3), 197-214.
5. Munasinghe, M. (2001). Sustainable development and climate change: applying the sustainomics transdisciplinary meta-framework. *I. J. G. Env. I*, **1**(1), 13-55.
6. Korhonen, J. (2004). Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology. *J. Clean. Prod*, **12**(8-10), 809-823.
7. Ayres, R. U. (1989). Industrial metabolism. *Technology and environment*, 23-49.
8. Allenby, B. R. (1992). Achieving sustainable development through industrial ecology. *International Environmental Affairs*, **4**(1), 56-68.
9. Jelinski, L. W., Graedel, T. E., Laudise, R. A., McCall, D. W., & Patel, C. K. (1992). Industrial ecology: concepts and approaches. *Proceedings of the National Academy of Sciences*, **89**(3), 793-797.

10. Bocken, N. M., Olivetti, E. A., Cullen, J. M., Potting, J., & Lifset, R. (2017). Taking the circularity to the next level: a special issue on the circular economy. *J. Ind. Ecol*, **21**(3), 476-482.
11. Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod*, **114**, 11-32.
12. McDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., ... & Doménech, T. (2017). Circular economy policies in China and Europe. *J. Ind. Ecol*, **21**(3), 651-661.
13. Ayres, R., & Ayres, L. (1996). Industrial ecology: towards closing the materials cycle. In *Industrial Ecology*. Edward Elgar Publishing.
14. Ehrenfeld, J. (2004). Industrial ecology: a new field or only a metaphor?. *J. Clean. Prod*, **12**(8-10), 825-831.
15. Lifset, R., & Graedel, T. E. (2002). Industrial ecology: goals and definitions. In *A handbook of industrial ecology*. Edward Elgar Publishing.
16. Ellen MacArthur Foundation. (2012). *Towards the circular economy*. Ellen MacArthur Foundation.
17. European Commission. 2014. *Moving towards a circular economy*. http://ec.europa.eu/environment/circular-economy/. Accessed October 2015.
18. Tong, X., Tao, D., & Lifset, R. (2018). Varieties of business models for post-consumer recycling in China. *J. Clean. Prod*, **170**, 665-673.
19. Yuan, Z., Bi, J., & Moriguichi, Y. Yuan, (2006). The circular economy: a new development strategy in China. *J. Ind. Ecol*, **10**.
20. Andersen, M. S. 2007. An introductory note on the environmental economics of the circular economy. *Sustain. Sci*, **2**(1): 133–140.
21. Pigosso, D. C. A., McAloone, T. C., & Rozenfeld, H. (2015). Characterization of the state-of-the-art and identification of main trends for Ecodesign Tools and Methods: Classifying three decades of research and implementation. *J Indian Inst Sci*, **95**(4), 405-428.
22. Bovea, M. D., & Pérez-Belis, V. (2012). A taxonomy of ecodesign tools for integrating environmental requirements into the product design process. *J. Clean. Prod*, **20**(1), 61-71.
23. EC (European Commission). 2009. Directive 2009/125/EC of the European Parliaments and the Council of 21 October 2009 Establishing a Framework for the Setting of Ecodesign Requirements for Energy-related Products (Recast). (2011). Brussels, Belgium: European Commission Energy.
24. Luttropp, C., & Lagerstedt, J. (2006). EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development. *J. Clean. Prod*, **14**(15-16), 1396-1408.
25. Tischner, U., & Deutschland, U. (2000). *How to do EcoDesign?: a guide for environmentally and economically sound design*. Verlag form Praxis.
26. Den Hollander, M. (2018). *Managing Obsolescence: Extending Product Lifetimes in a Circular Economy* (Doctoral dissertation, TU Delft).
27. Den Hollander, M. C., Bakker, C. A., & Hultink, E. J. (2017). Product design in a circular economy: Development of a typology of key concepts and terms. *J. Ind. Ecol*, **21**(3), 517-525.
28. Page, T. (2014). Product attachment and replacement: implications for sustainable design. *IJSDes*, **2**(3), 265-282.
29. Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm?. *J. Clean. Prod*, **143**, 757-768.
30. McQuillan, H. (2019). Waste, so What? A reflection on waste and the role of designers in a circular economy. *Nordes*, (8).
31. Kääriäinen, P., & Niinimäki, K. (2019). Towards Sustainable Textile Materials: Potential pathways and dialogues between disciplines. *Nordes*, (8).
32. Behrens, A., Giljum, S., Kovanda, J., & Niza, S. (2007). The material basis of the global economy: Worldwide patterns of natural resource extraction and their implications for sustainable resource use policies. *Ecol. Econ*, **64**(2), 444-453.
33. Van Ewijk, S., & Stegemann, J. A. (2016). Limitations of the waste hierarchy for achieving absolute reductions in material throughput. *J. Clean. Prod*, **132**, 122-128.
34. McDonough, W., & Braungart, M. (2010). *Cradle to cradle: Remaking the way we make things*. North point press.
35. Bakker, C., Wang, F., Huisman, J., & Den Hollander, M. (2014). Products that go round: exploring product life extension through design. *J. Clean. Prod*, **69**, 10-16.