Circular economy framework for sustainable product design strategies

Vesna Alivojvodic[1,*], *Jelena* Drobac[1], *Predrag* Maksić[1] and *Marina* Stamenovic[1]

[1]Belgrade Polytechnic, Brankova 17, 11000 Belgrade, Serbia

Abstract. Limited global resources, climate changes, growing population, combined with demand for sustainable products, indicate the need for change of existing production and consumption practices. In order of achieving more regenerative, restorative, and circular economy, design has been recognized as a catalyst for moving away from the traditional linear economy model (take-make-dispose). As shifting focus from quantity to quality, and finding new ways of working in cooperation with the nature, slowly becoming paradigm, it is important for designers committed to sustainability to have in mind environmental, social and economic performance of product design. This paper aims to address position of different product design strategies correlated with circular economy concept, as well as the opportunities for designers' to shift their mindset from the position of *creators* to *solution providers*.

1 Introduction

Creativity in reusing objects for different purposes, marked human history in many ways, but inherent creativity towards innovative reuse of resources has been lost because of cheap products that have become part of our everyday lives. Growing populations and scarcity of raw materials, as well as exponential and adverse increase in global environmental conditions nowadays, indicated the need to change existing production and consumption practices. Wasted resources (materials and energy), products with wasted lifecycles, or wasted capacity, and built-in values (components, materials, and energy) are four recognizable types of waste within a linear economy concept. Despite the fact that modern technologies can provide product design in a way that the value of incorporated materials can be recaptured for use in future products, or for up cycling of materials in a cost-effective manner, many businesses still operate in a linear way (wasting raw materials, and making new products with short lifespan). [1]

On the other hand, growing awareness of need to shift toward more sustainable way of consumption of goods resulted in several different schools of thoughts in last half of century, as an attempt to somehow “design out” waste. This deep rooted idea started formally to develop in 1970s, with the concept of Regenerative Design, and later through the Performance Economy, and Cradle to Cradle concept, then, through Industrial Ecology, and Biomimicry, up to the concept of Circular Economy of nowadays. [2]

*Corresponding author: valivojvodic@politehnika.edu.rs

One of the aims of circular economy is to provide high quality, functional and safe products, which are efficient and affordable, last longer, and are designed for reuse, repair, upcycling and high-quality recycling, with additional opportunity for developing whole new range of sustainable services, product-as-service models, and digital solutions that will bring about a better quality of life. [1] As a catalyst to obtain a shift from a traditional business-as-usual approach, to economic growth, but in sustainable way, special role has been given to design, in order to help to achieve a more regenerative, restorative, and circular economy. To obtain this, in other words, not only to help in shaping our world, but also to determining our impact on it, position of design within circular economy concept need to be considered within all its complicity, where design of sustainable products is only small but important part of the mosaic.

2 Circular economy and design principles

Shift from linear model of production and consumption of goods, has direct implications for the development of efficient and effective take-back systems and the expanding of product and business model design practices, in order to obtain more durable products, facilitate disassembly and refurbishment, and consider product/service shifts, where appropriate. [3]

The Ellen MacArthur Foundation has led the way in articulating the value of shifting global business models to circular economy. The circular economy according to them is based on a few simple principles to eliminate waste:

- Waste does not exist when the biological and technical components of a product are designed by intention to fit within a biological or technical materials cycle, designed for disassembly and refurbishment.
- It is important to build the systems more resilient in the face of external shocks, not only built simply for efficiency (building resilience through diversity).
- Try to rely on energy from renewable sources. [3, 4]

The “waste” can become a valuable resource, whose value can be captured by eliminating of [1,5]

- Wasted resources (through use of materials and energy that cannot be effectively regenerated over time, such as fossil energy and non-recyclable material).
- Wasted capacity (through products and assets that are not fully utilized throughout their useful life).
- Wasted lifecycles (through products reaching end of use prematurely due to poor design or lack of second-use options).
- Wasted embedded value (through components, material, and energy not recovered from waste streams).

With the aim to redefine the value of waste, five business models were developed within a circular economy concept (Figure 1.). Each of them can be taken individually, or combined, and they are not mutually exclusive, but using simultaneously can give the best results. Through these models minimization or even elimination of waste, pollution, and inefficiencies could be obtained. [5]

There are five underlying business models that Accenture has identified in its analysis of more than 120 case studies of companies that are generating resource productivity improvements in innovative ways. [6]

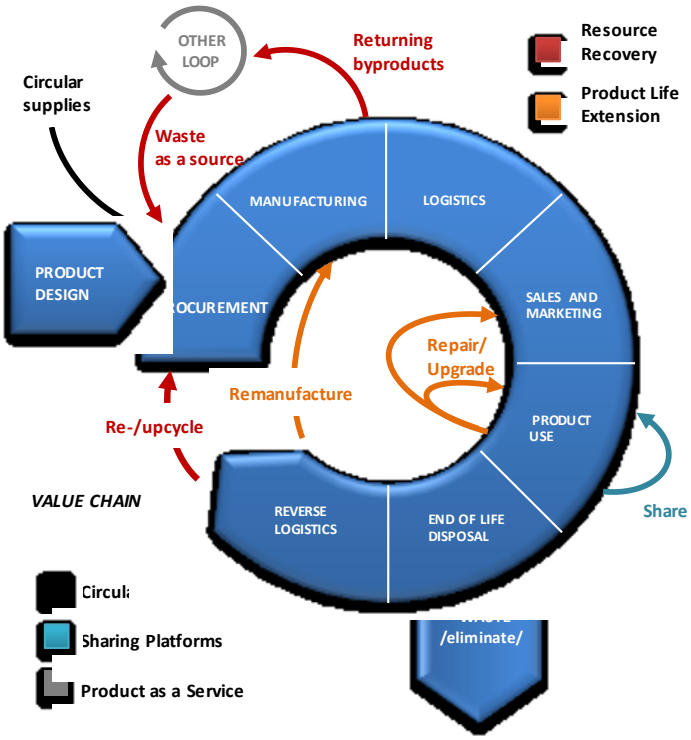

Fig.1. Five circular business models (*by Accenture*) [6]

While three of the models are more focused on production: Circular Supplies, Product Life (Use) Extension, and Resource Recovery, the other two: Sharing Platforms and Product as a Service, target consumption and the relationship between the product and the consumer. [1] Essentially, the models cover the full value chain of circularity.

Circular Supplies focus on the "ingredients" that go into products at the design, sourcing, and manufacturing stages. These inputs, such as renewable resources, aim to eliminate wasted resources (including toxic and single-use materials) and are a stepping stone for all other models. Product Life (Use) Extension focuses on maximizing the use of a product. To do so, companies have to start from the very beginning, from product design and responsible sourcing, in order to avoid wasted lifecycles and to keep products in use for as long as possible. [1, 5, 6]

In addition, Product Use Extension plays an important role in enabling the Product as a Service and Sharing Platforms models. The latter two go further by reinventing "product utility" in entirely new ways (e.g., buying a function or service, like mobility, rather than the product itself, a vehicle). Once a product reaches end of use, the role of Resource Recovery is to return the embedded materials or energy back into the production cycle, thereby "closing the loop" of the product from sourcing to usage and back to sourcing. [1]

Since design sits at the start of a product's lifecycle, with this position it is extremely important to incorporate circular principles.

As Richard Buchanan distinguish four domains of design (design of symbolic and visual communications,design of material objects, design of activities and organized services, and design of complex systems or environments for living, working, playing, and learning). [1]Sustainable design, as well as the design process itself, for each of these domains, as an extension, can incorporate broader strategies (even policies). Design can clearly no longer exist, and successfully practiced, without technology and economics.

Various disciplines, such as engineering and computer science, act jointly, and generate new forms of interaction. In future it will become increasingly important to develop and communicate design knowledge both vertically (within the discipline) and horizontally (between disciplines). [7]

Design strategies need to incorporate circular principles (Table 1.) to allow consumers to extend product usage, as well as to enable recovery of valuable materials (in other words to obtain product circularity). It is important to notice thatmore than 80% of the environmental impact of a product can be determined at the design stage. [3]

Table 1. Circular design principles [6]

Objectives	**Illustrative principles**
Product composition and production - use only circular or more sustainable materials	- Reduce or eliminate the need for materials and packaging - Use recycled/renewable materials and remanufactured components - Reduce stock keeping units and excess inventory waste - Choose alternative, less resource-intensive, and nontoxic materials - Design to eliminate or minimize waste during production processes
Product use - keep in useful life for as long as possible and reduce impact while in use	- Design for durability, modularity, repair/upgradeability, and efficiency while in use - Design to avoid single use and obsolescence - Deploy technologies to extend product use and enable recovery (e.g. for asset monitoring) - Deploy circular business models, designing products for sharing, leasing, and second life
Product recovery - enable materials or components to be easily brought back into a value chain	- Design for end of use disassembly, refurbishment and remanufacture (upcycling) - Choose materials that are recyclable or compostable at end of use

Today the majority of low-to-mid value products are designed for short-term use only (often with built-in obsolescence). Obsolescence is also an issue for high-value products (e.g. consumer electronics, with design features like seamless edges make disassembly particularly difficult). [6] Given the rapid pace of technology changes, obsolescence is likely to remain a considerable challenge in the coming years, highlighting the need for more circular design practices. [1, 6] On the other side, the problem definition for the product design will also come from deeper understanding of the goals the people are trying to accomplish, and the obstacles they experience.

3 Product design strategies

Defining design strategies to prolong useful life of product, for as long as possible and to reduce its impact while in use, starts with the notion that design concerns the whole economic role of the product.

For design of products within circular economy framework the goal is to provide high quality, functional and safe products, which are efficient and affordable, last longer and are designed for reuse, repair, and high-quality recycling. [8] Integrating circularity into product designs, can be a significant shift for teams of engineers, designers, and technicians that have traditionally been focused on cost or performance, to adopt a new way of thinking to incorporate new, principles. [1] Product design within a circular economy concept can be

referred as ”Circular Product Design“. [9] It is about keeping a product as close as possible to its original state over time, for instance through longer use, repair, upgrading, refurbishment or remanufacturing, in other words, extending the useful life of products is not just about recycling of materials. So far, the attention in that domain has focused mainly on closing the material gap, going from new to recycled, and back to (almost) new again.[9] In the case of production, this can lead to a combination of requirements, with respect to clean processing and efficiency, and in the period of product use, there is expectation towards sustainable consuming of energy, and preferably producing some. Ease of disassembling, or maintaining product's value through whole it's life cycle, are also desirable outputs of sustainable products. Also, by mean of better understanding of systems, designers can be able to identify the intervention points that lead to desired outcomes with existing products. To obtain all this currently six strategies have been defined, that can work perfectly well in certain combinations [9]:

1. **Design for attachment and trust**; Explores the way in which users develop a certain bond with the objects they use. Challenge: strategy only partly depend on designer influence.
2. **Design for durability**; – is based on defining optimum product reliability. It is a well-defined technical field. Ideally a product's durability should match its economic and stylistic lifespan.
3. **Design for standardization and compatibility** –is constantly evolving (field of digital technology, for instance).
4. **Design for ease of maintenance and repair**; This is complex field, having in mind that maintenance and repair are currently divided among the original manufacturer, the gap exploiting service provider and users.
5. **Design for adaptability and upgradability**; Implies to incorporate possibilities to change a product.
6. **Design for di- and reassembly**; Easy disassembly is a classic requirement for sustainability. The possibility to reassemble is similar to the previous three strategies, but may include assembly with components of other products to become something different.

If products ought to be easy to repair and disassemble, that starts with design. New business models for repair, reuse, recovery, and product as a service represent the area of opportunity. In 2018, IKEA, the world's biggest producer of affordable design furniture, received more than one million orders for spare parts from customers who were able to perform do-it-yourself repairs, thanks to the company's modular product designs. [10]

It became obvious that what is needed is a systemic shift across the product value line. With increasing Extended Producer Responsibility (EPR) legislation, however, products that need to be designed with circular and disassembly consideration will slowly gaining more attention of designer and innovation departments at leading organizations. Still, for the majority of those items, current marketplace economics do not yet encourage circular designs. [6]

4 Conclusion

Traditional linear economy model of production and consumption of goods could be replaced by circular economy concept. The full implementation of this new concept will result in a shift in perception within the design, because of the need to prolong product lifespan (a cornerstone of the circular economy). Design can become the catalyst for changes by putting focus from quantity to quality, and finding new ways of working in cooperation across different disciplines.

Having in mind that accepting and implementing product design principles within the circular economy concept is actually a difficult task, it is important to note that incorporating design strategies in other areas contributes to the development of sustainable products in the context of environmental, social and economic challenges. In order to further develop creativity within the product design process, greater connection between disciplines is required. Contemporary technologies provide the ability to design products so that the materials from which they are made can be reused of reused materials, slowing down material flow, while at the same time technologies enable material utilization in a cost-effective way. Consideration should be given to new methods of the design process as well as production habits, which would result in improved products and services, better customer relationships and savings of resources and energy. Through design, we can address some of the new solutions to identified challenges, by implementation of contemporary design strategies that include durability, standardization, compatibility, ease of maintenance, product repair, adaptability and upgrade, di- and re-assembly or incentivization of recycled materials to minimize waste, all in order to figure out most acceptable ways of closing materials loops.

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