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TRILOGY ON CIRCULAR ECONOMY

LAHTI UNIVERSITY OF APPLIED SCIENCES
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MEDKOVA, KATERINA: Trilogy on Circular Economy

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ABSTRACT

Circular economy has been on top of the EU agenda as a practical solution for global challenges on resources, environmental issues and social well-being. It has been said that circular economy can bring many opportunities, however, it requires system-level redesign. This change comprises of how we, as individuals and society, shift our values and how we function. Above all, it includes a change in how the system, products, and services operate and, primarily, how they are designed.

This compilation thesis discusses circular economy through a trilogy of connected articles. The first article elaborates the concept of circular economy based on a previous research. The second article is dedicated to urban mines, which can play a major role in the transition towards a circular society. Finally, the third article closes the trilogy by debating design for circular economy. This article manifests circular design as the key factor of the resource challenge our society faces and resonates with the principles of circular economy.

These thematically overlapping articles describe circular economy in a coherent document and thus contribute to increasing awareness and bring a better understanding of the paradigm.

Key words: circular economy, urban mines, urban mining, circular design

Lahden ammattikorkeakoulu
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MEDKOVA, KATERINA Kiertotalouden Trilogia

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TIIVISTELMÄ

EU on asettanut kiertotalouden etusijalle ratkaisuna maailmanlaajuisiin raaka-aine-, ympäristö- ja sosiaalisen hyvinvoinnin haasteisiin. Oikein suunniteltuna ja toteutettuna kiertotalous luo uusia mahdollisuuksia; toimiakseen se vaatii kuitenkin asenteiden ja toimintojen uudelleen suunnittelua ja arvojemme muuttamista. Ajattelutapojemme ja käyttäytymisen lisäksi muutoksen tulee koskea toimintaympäristön, tuotteiden ja palvelujen suunnittelua ja toimivuutta. Kierrätyksen esimerkiksi tulisi olla osa tuotteen suunnittelua.

Tämä kiertotalouden trilogia on kooste kolmesta toisistaan linkittyvästä kiertotaloutta käsittelevästä artikkelista. Ensimmäisessä artikkelissa kerrataan kiertotalouden käsitettä aikaisemman tutkimuksen pohjalta.Toinen artikkeli käsittelee Urban mining -konseptia. “Louhinta” ihmisten ja infrastruktuurin keskellä nähdään olennaiseksi tekijäksi tavoitellessamme kiertotalousyhteiskuntaa. Lopputyön viimeinen artikkeli lopettaa trilogian käsittelemällä suunnittelun merkittävää osuutta kiertotaloudessa ja globaalien resurssien paremmassa hallinnassa.

Esitetyissä artikkeleissa on tematiikaltaan luonnollisesti päällekkäisyyksiä. Ne muodostavat kuitenkin johdonmukaisen kokonaisuuden auttamaan konseptin ymmärtämisessä ja muutoksen tärkeyden merkitykset.

Asiasanat: kiertotalous, urban mines -konsepti, urban mining -konsepti, suunnittelu kiertotaloudessa

CONTENTS

ABBREVIATIONS

CI - Circular Indicators

C2C - Cradle to Cradle

IoT - Internet of Things

IT - Information Technology

EMF - Ellen MacArthur Foundation

EPR - Extended Producer Responsibility

EVA - Ethylene Vinyl Acetate

LCA - Life Cycle Assessment

MCI - Material Circularity Indicator

PEFC - Programme for the Endorsement of Forest Certification

RSA - Royal Society for the Encouragement of Arts, Manufactures and Commerce

UNEP - United Nations Environment Programme

VTT - Technical Research Centre of Finland

WEEE - Waste Electrical & Electronic Equipment

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“We cannot solve our problems with the same thinking that created them.”

- Albert Einstein

1 INTRODUCTION

Circular economy was a theme of the author's earlier Bachelor's Thesis, with the title Towards Circular Economy: EU, Finland and Lahti Perspective. The author decided to further develop this up-to-date topic in her Master's Thesis.

The form of the thesis was discussed with the staff of the Master's degree education in Lahti UAS, especially with the principal lecturer Eeva Aarrevaara. This thesis represents a new kind of experiment of a Master's Thesis at a University of Applied Sciences.

This thesis is an article based thesis, which is a form of a compilation thesis. It consists of three connected articles forming a coherent work on the common topic of circular economy.

List of the articles:

1. Article 1 - **Towards Circular Economy: EU, Finland and Lahti Region Perspectives**
2. Article 2 - **Urban Mines - The Mines of Circular Economy**
3. Article 3 - **Circular Design - Design for Circular Economy**

1.1 Research Approach

Article 1 summarizes the findings from the qualitative research, including literature review and in-depth interviews, which was integral to the Bachelor's Thesis.

Article 2 investigates rather a new concept of urban mining and discusses its key role in the transition towards circular society.

Article 3 is a natural outcome of Article 1 and 2, as both of the articles concluded that the design is the key to the resource challenge.

Both Article 2 and 3 are literature review – based. All three articles are accompanied by examples and real cases to support the theoretical part of the research. These pioneering cases help in building up a comprehensive picture of circular economy. Additionally, a few examples are introduced in the appendices. The overview of the Master's Thesis research approach is depicted in Figure 1 below.

The three articles are then bound together by a bridging article or a section, which is part of the introductory part of the thesis. This bridging section reinforces the linkages between the three articles and shows the relevance to the core topic of this thesis. Furthermore, it briefly summarizes the main insights from the articles. The full content of the articles, including the figures, are placed in separate chapters, following the introduction chapter.

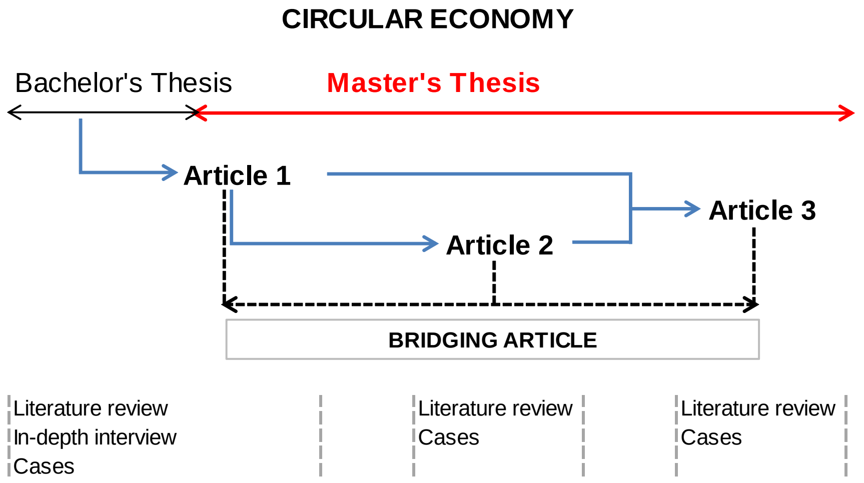

Figure 1: Research Approach Overview

1.2 Thesis Background & Contribution

The core article from the Trilogy is Article 1, which is based on the research and outcomes of author's earlier work on circular economy. The following two articles complement each other and further develop the topic and constitute the Master's Thesis.

The overall aim of this Master's Thesis is to raise awareness of a circular economy concept, its potential, as well as, its challenges. Furthermore, the thesis serves as food for thought and an inspiration for necessary actions and inevitable changes.

The topic of circular economy was chosen due to its importance and relevance to current global challenges: resource and energy availability and management, growth and creating jobs related to growing population, climate change, and the environment.

According to a report (2014) released by World Economic Forum, in collaboration with the Ellen MacArthur Foundation, over one trillion US$ could be generated by 2025 for the global economy every year. Moreover, 100,000 new jobs could be created and 100 million tons of waste could be avoided globally for the next five years by establishing "circular" supply chains with high recycling, reuse, and remanufacturing rates. (Towards the Circular Economy 2014, 4-11)

On 2 December 2015, the European Commission published an action plan towards a more circular economy. Together with previous policy actions (Including the Resource–Efficient Europe flagship initiative and roadmap, the European Industrial Renaissance and the Innovation Union flagship initiative), these proposed commitments uphold circular economy and resource efficiency in each and every stage of the value chain. (European Commission 2016)

1.3 Bridging Section

Article 1 provides the reader with basic information about today's megatrends and challenges our economy, society and environment face. Also, the concept of circular economy is elaborated.

Based on the Ellen MacArthur Foundation (2015), no single date or author can be connected with the birth of circular economy. Its roots, however, lead to a small group of academics, innovators, and businessmen in the late 1970s. The circular economy framework combines several schools, philosophies and principles together. These schools of thoughts are: Cradle to Cradle, Performance Economy, Biomimicry, Industrial Ecology, Natural Capitalism, Blue Economy and Regenerative Design. (Ellen MacArthur Foundation 2015)

A circular economy system, in contrast with the current linear economy, decouples the growth from resource consumption by keeping resources at their highest utility and value, and provides prosperity and safety to the society and natural capital. This is achieved by rethinking the 'take-make-dispose' consumption patterns and establishing restorative system by innovation and total system redesigning. In circular economy, the system is powered by energy renewable by nature, in order to enhance its resilience and resource independence. Naturally, the use of toxic chemicals is eliminated. Thanks to a circular design, aiming for optimized cycling within the system, waste is designed out. (Ellen MacArthur Foundation 2015)

Further, material flow, depicted in the butterfly diagram (Figure 2, page 13), is explained. The diagram in Figure 2, visualizes the flow and circulation of biological and technical materials in loops. As circular economy aims at minimizing any waste or leakages from the system, the focus should be on closing these loops. All the loops are equally important for a functional system, however, the inner the loops are and the longer a product circulate in them the higher original resource value and efficiency are achieved. These inner loops have a strong impact on local employment, economic and environmental aspects. For instance, repair and maintenance services should be organized locally to avoid extra transportation or delivery costs and to offer convenience for customers and users. (Ellen MacArthur Foundation 2015)

Another way how to close the loops is a different concept of ownership and a transition to a service economy in which goods are offered as services. Customers will become rather users and the product ownership would stay within the producer or manufacturer. As a consequence, the owners would aim for long-lasting durables, in order to maximize their profit margins and embedded value and, most importantly, preserve resources and capital costs essential for their business. Therefore, these durables need to be designed in the way that they are easily upgraded, dismantled, repaired or remanufactured. (Ellen MacArthur Foundation 2015)

The benefits for companies include both costs and revenues. Cost reductions appear from direct material savings, decreasing material price volatility risks and avoiding duplication of value-adding activities. In addition, producers can balance their losses from current direct sales by remarketing their products to secondary markets and giving a product a second, third or n-time life. Simultaneously, consumers and users can benefit from high-tech and good-quality products and services, which may not have been so far at affordable prices. (McKinsey & Company 2016)

The transformation to fully circular economy is a long journey. It takes time to implement and accustom to new ways of doing things, systemic changes and mental shifts. It takes time to establish supporting environment, collect the fruits of R&D, innovation, and technological breakthroughs. It takes time to design products with a whole lifecycle impact in mind and have a plan for repurposing activities in place. Yet, the population and demand for resources are growing and virgin materials are not. How to solve this unbalance during the transition period?

Today, 54% of the population lives in cities and the proportion is predicted to reach 75% by 2050. New cities need to be built and the current once need to be enlarged or rebuilt to accommodate the fast growing urban population. Simultaneously, an enormous amount of resources will be required. According to experts’ estimation, 60% of the future cities need to be yet born by 2050. (Vol 2016)

With the future prospects mentioned above, the demand, for instance, for metals and energy will rapidly increase. Metals are known as energy intensive in general, however, the intensity will grow even more. There are three reasons: (1) growing demand due to the urbanization, (2) shifting towards renewable energy technologies, and (3) declining ore grades requiring more energy to be extracted. (UNEP 2013, 20) How to enable long-term resilience, secure sustainable resource supply and the well-being of the planet?

The solution may offer urban mining, the topic described in Article 2. Urban mines are anthropogenic, as opposed to geological mines. Over the years, the treasures found in geological mines have been gathered in our urban environment in high concentrations. These concentrations of elements are several times higher than in their original deposits. In general, urban mines refer to materials locked up in buildings, structures, and products, or various applications and networks, such as cables, rail tracks or poles. (Yoshida & Yoshida 2011)

Resources contained in these technospherical urban mines have already been mined, refined and processed. Therefore, these materials, parts or components are less energy, water or emissions-intensive to reprocess. Recovering valuable and locally available resources from urban stocks can partially mitigate global resource scarcity and secure domestic material independence.

Systems thinking, or thinking in systems, enables us to see the elements that constitute the system as a whole, not the individual elements or pieces. Systems thinking focuses on the interconnections and relationships between these elements that hold the system together. (Aronson 1998, Ellen MacArthur Foundation 2015)

To unlock the urban mining potential, systems thinking is essential, for instance, when applied to the concept of material stocks and flows and their different dynamics (Circular Economy 2015). Article 2 defines three different types of stocks: In-use, Non-use and Prospective stocks (Figure 3, page 26). Today, the limitation of successful urban mining is also connected with the technical and economical inability of reprocessing complex materials and regaining the elements from structures. (UNEP 2011)

Urban mines is a relatively new idea and information regarding their size and location, time horizon indicating their availability, and eventually, their quality, concentration, and composition, are unknown. (Circular Economy 2015) This data is essential for a systematic coherent collection and secondary resource redistribution system.

Over centuries we have developed our geological mining abilities. The time has come to focus on a new kind of mines, the urban mines. Globally growing population calls for sustainable urbanization and sustainable cities.

The optimum resource circularity can only begin when the material stocks become saturated and large enough. When these stocks are due their residence time, then the outflow out of the stocks is available to be urban mined and circulate as a new material inflow in the system. Potentially a valuable circular material loops are established. However, some waste will occur, therefore, primary material inflow will be still required. However, the quantity of virgin materials used will become significantly lower. Stress should be put on diminished use of hazardous substances and searching for alternatives. If their application is unavoidable, then a closed system should be established. Their outflow complicates either their re-entering inflow to the system or while re-entered, it contaminates the system. (Circular Economy 2015)

Based on the literature review, a visualization of the urban mining position and role within the circular economy concept has been depicted in Figure 4 (page 31). Urban mines can contribute to redistribution and repurpose of resources within all the technical and biological loops of the butterfly model (Figure 2, page 13), presented by the Ellen MacArthur Foundation. Urban mining is more than just recycling, it includes recovery activities: reusing, repairing, remanufacturing, and resell, represented by green spirals in Figure 4 (page 31). All these “re-activities” can be reached through smart design for efficient products, components and materials circulation. Also, other important aspects, contributing to successful above-the-ground mining are shown.

The stress is especially put on design. Design thinking links all segments of the chain; product and material design with the system, infrastructure, and business model design. Urban mining is a prerequisite to smart resource management solution, which requires careful mining plan and databases for strategic actions in the future. Combining sustainable consumption and urban mining, design plays a key role in the transition towards more circular society and offers economic opportunities and environmental solutions presented in the circular economy framework.

As a consequence of the two previous articles in which the role of design for circular economy has been pinpointed, the topic of Article 3 was selected.

Article 3 tackles the overconsumption society, accumulation of stuff and unsustainable hunger for new stuff. Current producers, sellers and customers, but also current linear-structured economy and design, create an idyllic bubble with an assumption of resource abundance, no responsibility, and with no consideration of a product impact from ‘birth to grave’. ‘Sell fast, sell more’ and ‘buy new as you can’ approaches have prevailed. In the majority of cases, it has not been a producers concern, what happens with their products after sale, when they break down, get unused or obsolete. The solution to these norms was landfilling, legal or illegal, or incineration.

When resources have become more expensive, price volatile and some of them ever-scarcer, new policy regulations, limits, and recycling activities have arisen. Also, more and more consumers have required more sustainable production, products, and environment. However, all these green products were much more expensive and, therefore, not affordable for everyone. Even with the new incentives and strategies, like Extended Producer Responsibility (EPR) in place, products were downcycled and shredded into secondary material mixtures. In the majority of cases, these products were unrepairable, unupgradable, unremanufacturable. The main reason was that they were never meant and, therefore, designed to be reused or their contained value to be recaptured.

With a circular economy arrival, circular design thinking is strategic as it determines the overall product's lifecycle impact, its rebirth, or end-of -live activities. It takes into account utilization of by-products and wastes. Same as circular economy, circular design focuses on environmental, economic and social aspects. It strives to deliver an optimal and functional products or services, with the balanced performance while minimizing its negative impact along the whole life cycle (Aho 2016). Simultaneously, the circular design aims to retain the embedded value in products better than before by ensuring materials circulation with or even within the same application.

New circular products bring new business opportunities and thus require new business models to fit the circular economy concept. Article 3 points out five business models developed by Products That Last project. Moreover, six strategies for circular product design are identified with their aim to counter obsolescence and keep a product as close as possible to its original purpose. (Bakker & Hollander 2013; Bakker et al. 2014) Several existing examples of these strategies and business models are delivered to a reader not only to help a better understanding but mainly to highlight the existence of these pioneers.

Based on the finding of the Ellen MacArthur Foundation's Circularity Indicators Project (2015), no circular economy metrics and systems thinking based methodology exist. However, a few new tools and methodology for circular design are suggested in Article 3 to guide designers in their decisions. Similarly to circular economy, circular design is possible only through cooperation and collaboration with stakeholders from various fields.

At first, design should be understood as a verb, a process or an action, only then as a noun. Concluding the complexity of findings from previous articles and a literature review, a Circular Economy Design Concept is depicted in Figure 9 (page 54). The concept is built on the four lines of discussions (Systems Thinking, Awareness, Mental Shift, and Communication) around the four elements (Circular Design Strategies, New Business Models, Cross-disciplinary Intelligence, and System Conditions). Continuous questioning and redesigning processes reflect the outcomes of lines of discussion around changes and priorities of our choices, enabled by the four elements. Also, the overall symbiotic impact of circular economy design on three dimensions: People, Planet and Profit, is emphasized as they both drive and are driven by circular design and influence the redesign processes in circular economy.

The success of circular design or circular economy does not merely depend on designers. The whole system needs to be transformed, from innovative thinking and working, to building the infrastructure, policies, and new technological solutions. Information and knowledge need to be shared and exchanged through an active dialogue between all the players. The role of cross-disciplinary education, in the transition towards a circular economy, is major as new skills and competencies are required.

Finally, mental shift and change in our attitude can be reached only if provided awareness, communication, and supportive environment.

2 ARTICLE 1 - TOWARDS CIRCULAR ECONOMY: EU, FINLAND AND LAHTI REGION PERSPECTIVES

Katerina Medkova and Sakari Autio

Introduction

This article is based on research conducted as a part of a Bachelor's Thesis in Lahti University of Applied Sciences during autumn 2015. The objective was to explore the circular economy concept and to define its potential stimulants and existing challenges. The goal was to present examples and cases and thus raises the awareness and understanding of circular economy.

First, the vast sources of literature were reviewed and served as a foundation for the empirical part of the research. In the empirical part, altogether six in-depth interviews were done. Their aim was to obtain enriching opinions from various sectors, from governmental and public sector to a local service provider and a researcher. Thereafter, these findings were analysed and compared with the theoretical facts.

Circular Economy Concept

The unsustainable exploitation of natural resources, the globally fast-growing population (now over seven billion inhabitants) and the sought economic growth cause a continuously increasing demand for food, water, materials and products, energy and even space. As a consequence of these megatrends, the Earth will eventually go bankrupt. Based on the European standard of living, the world population would require four planets to meet the needs. Yet, we still have only one planet. Some of the natural resources are already becoming scarce and this has a direct impact on our economy. Also, the environmental pressures caused by human activity, as well as declining biodiversity and high unemployment need to be addressed.

Our current economic model, the linear model, is based on the assumption of an abundance of cheap and easily available natural resources, as if there had been and always will be a never-ending supply of virgin materials. The ‘take-make-use-dispose’ approach leads into enormous wasting of natural resources and waste is considered something with no value. Materials are lost and often contaminated.

Today’s producer-consumer system is based on producing quantity rather than quality, with products that have a relatively short life cycle and build-in obsolescence in order to sell new products and new models, without paying attention to what happens with the disposed products. Disposal is not often part of the producers’ responsibility or even interest. This alarming unbalance calls for a change, urgently. A solution can be seen in a new model of circulating resources, a circular economy.

A circular economy is a wide concept based on several schools of thought and, therefore, no single date or author exists. The framing philosophies are: regenerative design, performance economy, cradle to cradle design philosophy, industrial ecology, and biomimicry.

The restorative model of a circular economy regards waste as ‘food’ or resource for new processes. Waste is seen as a valuable bank of nutrients, materials and energy. In fact, this approach creates resource abundance. Its principles are based on minimizing the impact on the environment and the waste creation as close to zero as feasible, and eliminating the use of toxic chemicals. Ultimately, the system is powered by renewable energy. The added value in products is kept as long as it is viable, and the closed loop systems bring benefits for the economy, environment and society. The concept accelerates job growth and builds long-term prosperity, well-being and safety of society and the ecosystems.

One of the major goals of a circular economy is to decouple the economic growth from the resource consumption by promoting innovation, smart design and co-design, knowledge sharing, and cooperation and collaboration. In the circular economy, nutrients and materials are intentionally designed to cycle in closed loops, in the same way as in nature's biological cycles.

The material flow is depicted in Figure 2. The butterfly diagram illustrates the flow of (1) the biological nutrients, on the left, which are designed to safely re-enter the biosphere and (2) the technical materials, on the right, which circulate within the techno-sphere with a minimal loss of quality and value. This metabolism is driven by the use of renewable energy. Biological and technical materials circulate in loops. A circular economy aims at closing these loops to avoid any leakage. The closer to the centre the loops are and the longer the products/materials stay there, the higher value is preserved and the more resource efficiency is achieved.

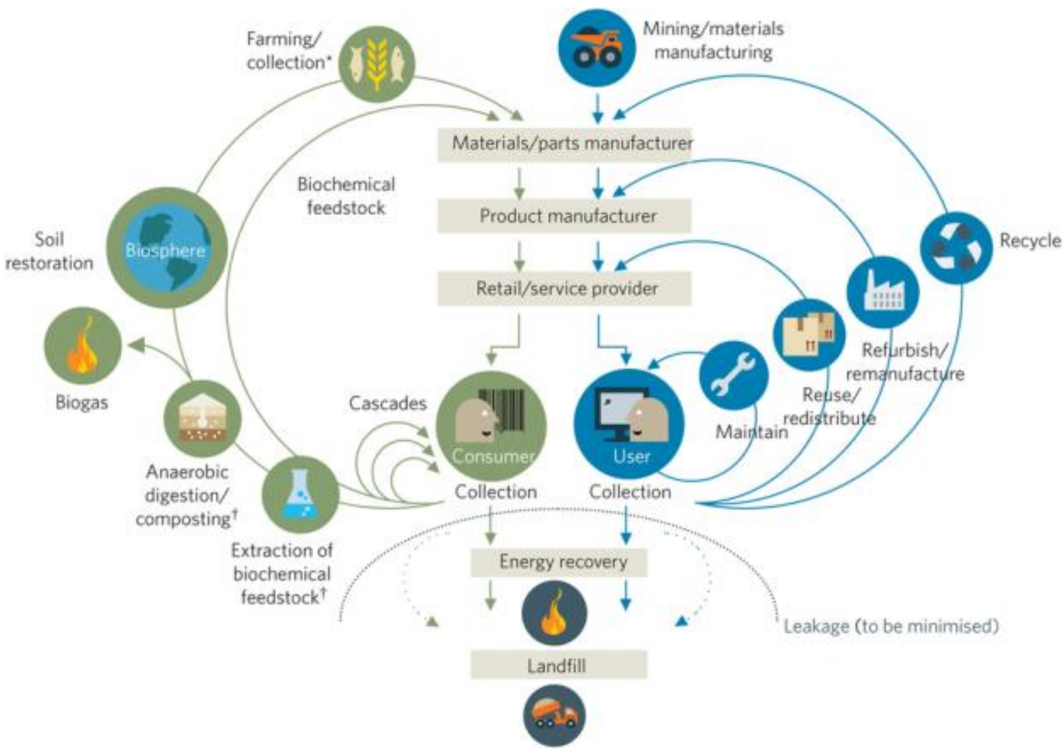

Figure 2: Material Flow Diagram (Ellen MacArthur's Foundation)

As Stahel stated: "Don't repair what is not broken; don't remanufacture what can be repaired; don't recycle what can be remanufactured." If the circulation of the inner loops, in particular, is organized on a regional level, it supports job creation and there are considerable economical and environmental savings due to avoiding double transportation.

To make the loops as closed as possible, the concept of ownership needs to change. Instead of selling goods, producers and manufacturers would sell their goods as services. In other words, customers would pay for the use of products. As an example, we would buy hours of lighting service, not bulbs and electricity, or lighting devices. Similarly, we would buy mileage of transportation service, not necessarily a car, which stays idle most of the time. This way, the producers remain the owners of goods. Consequently, the impetus is to develop durable and long-lasting products that are designed to be easily upgraded, dismantled, repaired or remanufactured, in order to secure the profit and preserve resources essential for the business. Simultaneously, consumers gain better, high-tech and good-quality products and services for use. By becoming service providers, producers could extend their services to maintenance and repair, which would boost regional employment.

The smart design and the inner loops (reuse and refurbish) give producers an opportunity to remarket products and extend the customer base to the secondary markets, offering quality reprocessed products at affordable prices.

Drivers, challenges, enablers

In the empirical part of the research six in-depth interviews were done. The respondents found, similarly to the Ellen MacArthur’s Foundation and other sources, among the biggest drivers (1) the scarcity and volatile prices of natural resources, (2) the potential for new businesses and thus job growth, followed by (3) the boom of EU legislation and support. Also, (4) the shift in some consumers’ behaviour and their orientation from goods’ ownership towards services was regarded as important.

At the same time, some of the drivers were seen as challenges or obstacles of the change towards the new economic model, such as maintaining the status quo of material possessions. In some cultures, this represents a cultural and psychological stress. Ownership is connected with personal or group identity and, therefore, this undisputed norm should be addressed delicately. Maybe, it is time to change the norms, but without forerunners it is not possible.

According to the respondents, the biggest challenge is to change people’s attitude and way of thinking. One of the respondents quoted aptly: “It is easier to run the business the usual way.” During the past years, many new terms and definitions have arisen. Some are wrongly used interchangeably and that creates confusion among the general public. Based on the interviews, this is also the case of circular economy, leading to circular economy being another synonym to recycling or waste management.

The lack of financial and legislation support of various forms was regarded as a barrier. The disharmonized legislation is one of the obstacles; as an example, the status of waste/ product was pointed out. To complement the respondents’ view, the literature review revealed that the current challenges also include missing targets for reuse and remanufacture, reliable information and quality standards for secondary materials. The lack of quality standards partly explains why producers prefer virgin materials to secondary materials. Also, it is a fact that due to available technologies these secondary materials are often more expensive than virgin raw materials.

The respondents also stressed the importance of the general awareness and innovation needed to develop concepts convenient enough for consumers to make the change happen, as well as to create the infrastructure for producers and manufacturers.

Limitation of the model

When debating on the limitations of the model, the vast majority of the interviewees agreed that the limits are in our heads, in people's minds; the current system and available technologies also restrain the transition. Supporting legislation plays a role too, as the current legislation is built for the linear system, in line with the theoretical findings.

The mindset of all the players needs to be changed. Consumers need to see the benefit in the availability of quality products and service to use, which they might not have been able to reach so far. On the other hand, there is a risk of the rebound effect, since more products and services will be used as they will become available to more people. Also, the mindset shift includes consumers' perception of secondary or reprocessed products, as they might represent a social barrier, something of a lower quality.

Producers and manufacturers need to acknowledge that the model offers many business opportunities, even though some of the companies might no longer exist if they are not willing to adapt to the new conditions. The current policy of any enterprise, to sell more goods fast, needs to be transformed into eco-effective and eco-efficient products and services that last long. The core of the business remains the same, to make profit and satisfy customers. On top of that, the aim is to protect the environment by designing products smartly.

The transition from a product-owning model to a result- or service-oriented model is not easy. From the producers, it requires heavy pre-financing of goods. The infrastructure for maintenance and repair needs to be organized and attention also has to be paid to the various systems of goods acquisition and collection back from the consumers/users. In many cases, the volumes might be rather small, so a sophisticated system is required.

Findings

Based on the interviews, we rather concentrate on the outer loops, such as recycling and waste management. However, when the discussions come to the point of recycling, it is actually too late, as we let waste occur. It means that we have literally wasted the great material value through many of the present recycling processes. In most of the cases we talk about downcycling, not upcycling, as the products are, in most of the cases, shredded and often mixed with materials, which were originally not specifically designed to be recycled. Recycling has its significant place in the circular system, but it is only a small fragment and the weakest loop in terms of preserving the material value. By focusing on recycling and waste management, we approach the resource challenge backwards, from the end.

Currently, the attention is also on the repair and reuse loops. This is a huge step forward, but it is still a backward approach to the challenge.

Instead, the spotlight should be on product design, the starting point of the resource challenge. Thanks to smart product design and co-design, the overall life-cycle impact can be influenced and waste creation prevented. The dismantling, repeated reuse and remanufacturing of the product, along with its durability, eco-effectiveness and eco-efficiency are the foundations of smart design, before the product is born. The following loops would then be tailored to the novel designs.

It is similar to planning a dinner for your guests with special diets or allergies. Which approach is better? Either preparing the menu according to the guests' food restrictions and considering the ingredients and their potential impact, or not paying attention to the preparation phase and serving any kind of food and trying to deal with the reactions, putting the guests' health at stake, and wasting the time, energy and resources while making this menu?

However, it is necessary to see the holistic view, where all the loops and activities have their role and place. It is important to remember that these flows are not always circular. The circularity is limited by our knowledge and technological solutions at the given point of time. Moreover, it is caused by the system dynamics, which are evolving, in the same way as humankind. Therefore, we need continuous development and innovation of our solutions.

Conclusions

A circular economy offers us a novel approach to our untenable consumption of natural resources. The concept presents immense opportunities by embracing the economic, environmental and societal needs. Though its principles are rather simple, it has enormous implications for our living and consuming patterns, for our values and way of thinking, and even doing business. Based on the research, the biggest limitation is in people’s minds. The transition requires social innovation, technological breakthroughs due to the currently limiting solutions, and redesigning the entire system level. Certain obstacles relate also to the economical interest groups involved in the present status quo of natural resources extraction, production, consumption, and recycling.

The implementation of circular economy is a dramatic change, which would not happen overnight. A lot needs to be done, a lot needs to be thought, and a lot needs to be communicated.

All the players ought to be engaged in the process; not only producers and manufacturers, but also consumers, municipalities, scholars, organizations and the general public. The change can be successful only if the knowledge, experiences and values are shared, requiring mutual cooperation and collaboration. Furthermore, a combination of an array of policy instruments, economic tools and various factors and mechanisms, the ‘Support’, together have a synergy effect on the transition.

To make the transition happen, the success lies in raising public awareness of the circular economy principles, the ‘What’, but most importantly, the reasons for the change, the ‘Why’, in order to get people to strive towards the same goal. Public awareness together with the ‘Support’ of various enablers creates the stimulating environment and food for innovative thinking and solutions of ‘How’ to accomplish the transformational mission.

The future is circular!

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3 ARTICLE 2 - URBAN MINES – THE MINES OF CIRCULAR ECONOMY

Katerina Medkova and Brett Fifield

Abstract

Global population and demand for resources is rapidly growing, although sources of virgin materials cannot. Natural treasures, which we take for granted, occurring in geological mines are, in fact, limited. However, there are other mines full of resources, richer than any natural deposits can offer, which we do not yet fully appreciate. These mines are anthropogenic; they are called urban mines. In general, urban mines refer to materials in products, buildings, and urban infrastructures. And unlike the rather scarce geological mines, there is an abundance of locally accessible urban mines in every country, in fact, in every city. Urban mining can play a key role in a sustainable resource supply and the transition towards a more circular economy.

This paper aims at discussing this concept of urban mines and its potential benefits to the economy, society and environment based on available examples and cases. How much can we gain? Urban mines is a relatively new idea, and not much research has been done regarding their size, time and location availability. We are only beginning to fully appreciate the potential riches of our contemporary urban mines.

This paper also reflects on the idea of future urban mines described as a possible solution for effective and efficient urban technospherical materials management. It is a long-term and complex challenge. However, imminent actions are necessary. Among other solutions, smart design functions as a link between all segments of the chain; from product and material design to system, infrastructure and business model design. By considering sustainable design thinking and urban mines as an approach to managing the equilibrium of material flows and stocks in the future, we can support growth without consuming all of our natural resources. This paper

discusses what has been done so far, points to the current barriers, and proposes directions for future development.

Keywords: Urban mining, future urban mines, circular economy, data mining, material recovery, technosphere mining, sustainable resource supply, smart design.

Introduction

In general, circular economy addresses the economic, environmental and also social areas of our lives. It strives towards using resources more wisely as they become more scarce or are more difficult and less profitable to extract. There are several access challenges: technological, economic and environmental, and impacts related to health and safety. Furthermore, geopolitics and location play a role as well, as the supply of some materials depends on a few mines worldwide. (UNEP 2013, 4)

If the urban population doubles in the next three to four decades, then new cities, infrastructures and more food, products and services will be required. The circular economy proposes, by maximizing the preserved value and cascading materials across industries, that we extend the material circularity longer and increase effectiveness and efficiency, and thereby, reduce raw materials demand. (Medkova 2015; Towards the Circular Economy Vol 1 2013; Wheels of Metals 2014)

This paper is based on a literature review. As the topic of urban mines is new, the sources are rather limited.

What Is Urban Mine?

Manufactured products are richer in precious metals deposits than in their original ores. It also requires less energy to refine those materials from products. Professor Nanjyo of Tohoku University of Japan coined the term Urban Mine in the 1980’s. Using this term, Professor Nanjyo classified designated sites for storing discarded products, in order to mine these valuable metals. Originally, these urban mines sites were proposed for end-of-life vehicles, packaging waste, WEEE (Waste Electrical & Electronic Equipment), batteries, used paper and construction rubble. Designating urban mines were part of the Japanese move to a circular economy, aiming at lower virgin material use and thus creating more sustainable environment. (Yoshida & Yoshida 2011)

In another study, Prof. Nishiyama showed that “80% of the world’s mercury, 75% of silver, tin, and lead, 70% of gold and zinc, and 50% of copper and manganese have already been used aboveground” (NIMS NOW 2008, 2).

The urban mines concept is still in its infancy. Ambiguity about the term exists because of differences in how the term is used. Some people might understand urban mines as synonymous with recycling or recovery. For instance, urban mining is often associated with metal recovery, especially from WEEE and referred to literally as gold mines of e-waste, due to a higher concentration of gold and other rare metals than in the primary ores.

Another use of the term refers to all materials that are present in our cities. Originally, an approach to recapturing metals from products could, in fact, be extended to examine the recapture value of other materials readily at hand in our urban environments. Currently, we are limited to economically feasible materials recovery by our limited understanding of how to reprocess complex materials, which are embedded in the elements of structures. (UNEP 2011)

These reprocessed recovered materials are referred to as flows and stocks. Urban mines are stocks of materials, which are contained in buildings, old factories, bridges, infrastructures, or various applications and networks, such as cables, unused rail tracks or old telephone poles. Additionally, discarded products, such as mobile phones, TV’s or old vehicles, are also stocks. And finally, there are stocks contained in ships and vessels, planes and army equipment, spaceships and abandoned satellites in space. (Yoshida & Yoshida 2011) All of these categories represent types of technospherical urban mines, providing resources, which are less energy intensive to reprocess and minimize environmental risks.

In addition to metals, other obvious materials could be considered for urban mining. These materials are plastics, wood, glass and biological materials. A less obvious opportunity for urban mining can be found in urban agriculture. Cities have been regarded as “one-sided consumer of natural resources”, however, cities are also producers and possible suppliers of local resources, such as biowaste and water, with respect to circular economy flows (Giseke, Gerster-Bentaya, Helten, Kraume, Scherer, Spars, Amraoui, Adidi, Berdouz, Chlaida, Mansour & Mdafai 2015, 31).

These materials have already been mined, refined and processed. They are an easy source of materials. By not understanding the concept of material stocks and flows as a system, we do not fully utilize the potential of urban mining.

Thinking in Systems, Material Stocks and Flows

Thinking in systems, sometimes called systems thinking, is at the core of the circular economy concept. This means looking at the complex systems of elements, relationships, and interactions as a whole, not as individual elements.

Another way of looking at systems thinking within the circular model is the concept of material stocks and flows. We can define a material stock as an urban stock of materials contained in products, applications, and infrastructures accumulated in society. These materials could be presently being used or not, however, they have not yet reached the waste stage. A flow of materials can be described as a combination of a material inflow into the stock and a material outflow out of the stock. In other words, the amount of a material extracted for building the stock in a year (inflow) and the amount of a material recovered out of the stock in a year (outflow). The difference between the inflow and outflow composes the stock. (Circular Economy 2015)

The stock grows if the inflow is bigger than the outflow out of the stock and this is what we are expecting to happen, because the population and demand will grow. If the outflow is bigger than the inflow into the stock, the stock depletes. The stock's dynamics drive the material flow (inflow/outflow). When the inflow equals the outflow, the stock reaches equilibrium. And that means, the inflow here, is to maintain the level of a stock and compensate the waste outflow out of the stock. When the circular economy reaches the equilibrium stage, the outflow becomes a new secondary material inflow, with a close to zero need for virgin materials. (Circular Economy 2015)

Types of Stocks

There are three different types of stocks: In-use, Non-use and Prospective stocks (Figure 3). Each stock has its characteristic dynamics and understanding these dynamics is crucial for steering society towards more sustainable development and circular economy.

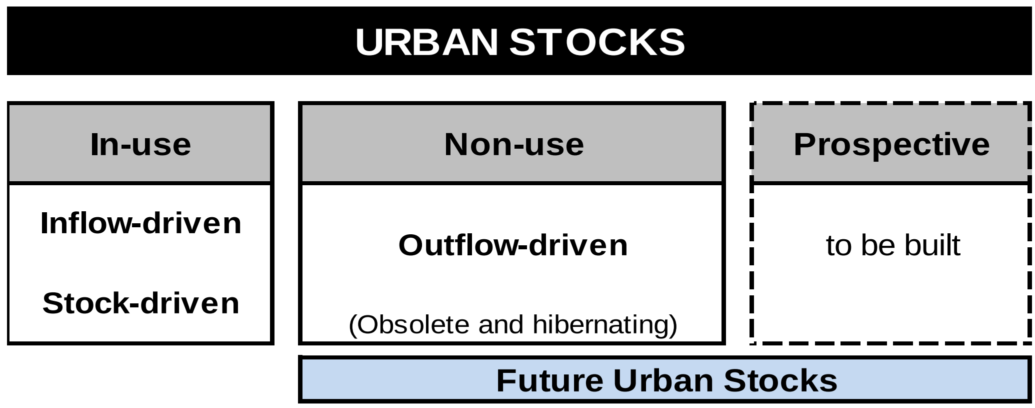

Figure 3: Types of Urban Stocks

In-use stocks consist of Inflow-driven and Stock-driven stocks. Inflow-driven stocks have a very short life span of several weeks or months, and a stock as such is almost not formed. A typical example can be packaging, such as beverage cans, which are discarded immediately after use. The inflow equals the outflow only over a short time delay. On the other hand, stock-driven stocks are stocks of goods and materials, which we aim to accumulate or maintain at a certain level to become saturated stocks; for instance, infrastructures, buildings, and cars. In this case, the outflow equals the inflow of some years ago. The time difference equals the utilitarian lifespan or a residence time of an application. (Wheels of Metals 2014)

Non-use stocks are outflow-driven stocks, including goods and materials which are not used anymore and have become obsolete. These obsolete goods and materials are like waste but they have not entered the waste stage yet, instead, they are hibernating and waiting to be mined. One of the reasons can be that these hibernating anthropogenic stocks have a potential to be recovered, however, it is not economically feasible at the time. Examples of this would be materials in tailings, government repositories, industrial stockpiles, and landfills (UNEP 2010,12). Other examples of non-use stocks could be old cables or tubes left in the ground, abandoned buildings and cars, or old electronic devices, left in drawers, attics and basements. (Wheels of Metals 2014)

Prospective stocks are stocks of applications still in a planning phase, including new cities, infrastructures and goods that will meet the rising demand of rapidly growing population and urbanization in the coming decades.

Both, non-use stocks and Prospective stocks form Future Urban Stocks; the future material deposits to be mined from the anthroposphere. Especially here, the future mining plans and databases, smart product design applications, residence time estimates as well as product or material passports can be and ought to be implemented already in the planning and designing phase, to improve the efficiency and effectiveness of future urban mining. Here, the role of non-use urban stocks is substantial. It can provide needed resources for building future cities and connected applications.

An inspirational example comes from the Netherlands, where several buildings were renovated and combined with new ones. Not only is this building complex energy positive, and 80% of original materials were reutilized, furthermore, 80% of the current structure materials can be reused again beyond the structure's end of life. And even here, material passports play a critical role in the circular economy by providing "information on all of the materials used within the building, including their lifespan and potential opportunities for reuse". (Egerton-Read 2015)

Urban Mining Benefits

Urban mines are positioned where people live. This brings environmental, socio-economic and logistical advantages.

Recovering secondary materials from urban stocks can partially mitigate global resource scarcity and secure domestic supply and thus create material independence over import. By minimizing traditional mining and logistically using locally available resources as secondary materials, a huge amount of energy, water and emissions can be saved. The energy and emissions requirement of secondary metals in comparison with primary produced metals is between 50 to 99% (Corder & Golev 2015). In the case of energy intensive aluminium, 95% of energy can be saved, thus avoiding 9 tonnes of carbon dioxide per tonne of recycled material (Cianciullo 2016).

Products and Applications

A study (2013) by the Ellen MacArthur Foundation revealed that 65 billion tonnes of materials were extracted from nature in 2010, and consumption is expected to reach 82 billion in 2020. Europe itself generated 2.7 billion tonnes and only 40% of this amount was reused, recycled or composted. UNEP presented examples of annual value losses for some metals; USD 52 billion for copper, USD 34 billion for gold, USD 15 billion for aluminium and USD 7 billion for silver. (Towards the Circular Economy Vol 1 2013)

Electronic products are made from valuable resources and materials, including metals, plastics, and glass, all of which require energy to mine and manufacture. Up to 60 elements of the periodic table occur in electronics in general. According to the United Nations University, the global quantity of e-waste generated has risen from 33.8 Mt in 2010 to 41.8 Mt in 2014. The forecast for 2018 reaches 50 Mt of e-waste. (UNU 2014, 22-24)

The estimated material value of global e-waste hit almost 48 billion Euros in 2014. More detailed analyses are in Table 1. The vast majority of these valuable materials are either in use, hidden or even lost in our urban mines, including landfills. Only 6.5 Mt of e-waste was documented and recycled in 2014. (UNU 2014)

		Material	Kilotons	Million Euros
Metals		Iron, Steel (Fe)	16,500	9,000
		Copper (Cu)	1,900	10,600
		Aluminum (Al)	220	3,200
	Presious Metals	Gold (au)	0.3	10,400
		Silver (Ag)	1.0	580
		Palladium (Pd)	0.1	1,800
Plastics		PP, ABS, PC, PS	8,600	12,300
				€ 47,880

Table 1: Global Urban Mines, based on UNU 2014

In general, WEEE waste contains 40-50 times higher concentration of precious metals and minerals in comparison with natural ores. In the case of mining gold from gold ore, the yield is three to five grams per ton. In comparison, from one ton of urban ore, such as PC circuit boards, the yield is 200 to 250 grams per ton; in the case of mobile phones, it is possible to extract even 300 to 350 grams of gold per ton of phones. (Grant 2016, 22)

What Needs to Be Done

To some extent, urban stocks are utilized in recycling paper, metal, glass and bio-waste. However, there is no mining plan and database for urban mining actions in the future. Quantifying urban stocks is important. The UNEP (2010) report confirmed that available data is limited or non-existent. Some information about in-use stock and lifetimes exist only for five metals, aluminium, copper, iron, lead, and zinc and there is scattered information about 19 other metals.

The same methods used by mining companies to explore potential mines and prepare a mining plan by exploring the geological properties, mineral concentrations, economic viability and environmental aspects, should be applied in investigating urban mines potential. (UNEP 2010; Wheels of Metals 2014, Circular Economy 2015)

There are three considerations in urban mining. First is the size and location of the stock. Secondly, it is the time horizon, in other words, the lifespan, indicating when the various material stocks will be available for mining. The lifespan is different for different applications; for buildings the material can be locked for 50 years or even more, for a car the time may be in between 10 and 20 years, and packaging material can be available within weeks or months. Thirdly, it is the quality, concentration, and sort or composition of materials present in the stock. (Circular Economy 2015)

In Figure 4, the position of urban mining within the circular economy concept is depicted. First, primary materials are extracted from the geological mines and turned into materials and products, which are then accumulated in different types of material stocks in our society. In order to successfully mine them, the dynamic of material flows needs to be understood. Then, the harvested materials from urban mines can become secondary materials for production. However, urban mining goes beyond recycling; it includes other activities promoted by circular economy, such as reusing, repairing, remanufacturing, recovering and recycling, which are represented by the green spiral in the figure. Urban mining can provide a supply of products or their parts for remanufacturing and repair. It could also function as a collection point for products, which can be resold. This could only happen thanks to smart products and material design which ease repair, remanufacture and eventually recycling. Here, the product-material passport and urban mining plan are fundamental. An urban mining plan should be embodied in master urban plans of potential future stocks. Circular economy aims at minimizing leakages, however, some material loss will always appear. Therefore, the need for primary material will still exist, however, at a reduced level. Figure 4 depicts the importance of other supporting aspects, not only in urban mining but in a circular economy in general.

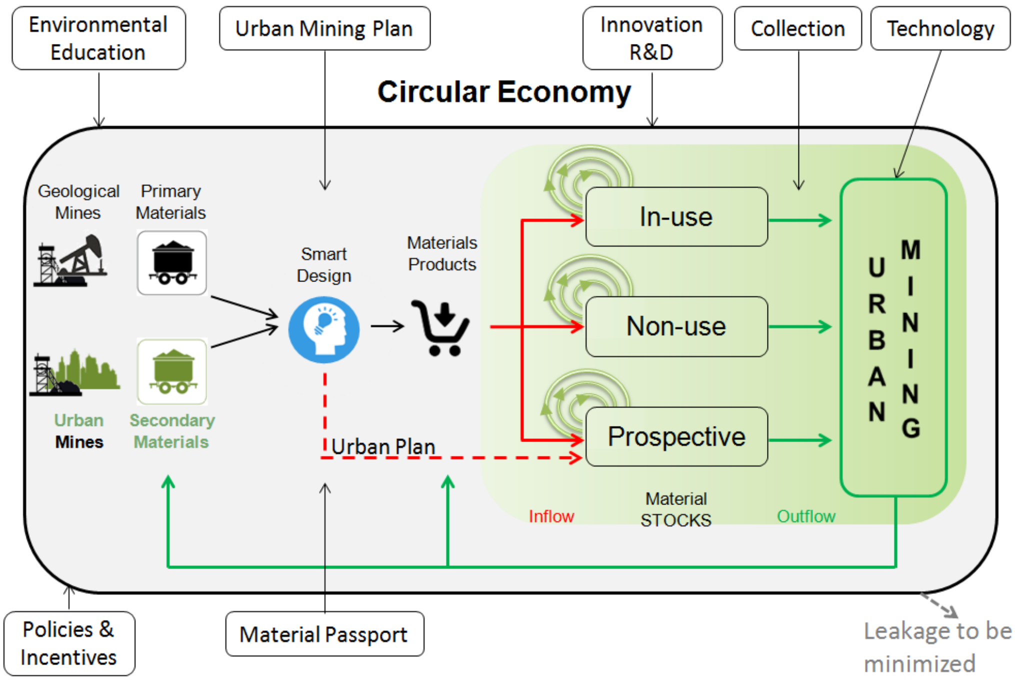

Figure 4: Urban Mining within the Circular Economy

Urban mines can be a valuable part of a circular society by redistributing and repurposing resources within all the loops of the technical and biological cycles of the butterfly model, presented by the Ellen MacArthur Foundation. (Ellen MacArthur Foundation 2016)

Efficient urban mining technologies and new smart technical solutions for retrieving materials from complex waste streams need to be planned for and implemented. Collection systems and incentives for returns of, for instance, consumer products, industrial machines and equipment and vehicles need development. In order to make the system work, we should not ‘fix it’ in retrospect. We have to look at the beginning of the whole process before products and materials are born, the design phase. (Medkova 2015)

The design involves not only new applied technology, but overall conceptual change on products and materials used, so they can be easily reintroduced into the system. Developing smart production and material design extends the product life cycle and eases the refurbishment and dismantling for recycling. The same applies to developing recyclable materials. Smart design can be achieved only when all the players are part of the co-design; designers, engineers, economists, environmentalists, as well as producers, manufacturers, and consumers. (Medkova 2015, 67 - 78)

Technology and Technical Challenges

Material complexity complicates recovering of materials from urban wastes, obsolete products or buildings. Also, the trend towards utilization of complex materials in everyday products has boomed. For instance, the complexity of the elements in Intel’s computer chips has risen from 12 elements in the 1980’s up to 61 elements in the 2000’s. Subsequently, there is a challenge in regaining these elements from the complexity of materials. (Wheels of Metals 2014)

Extraction, recovery and reprocessing methods from urban deposits ought to be established. Simultaneously, meaningful business opportunities for developing mining equipment, technologies, services and follow-up processes are engendered. (Corder & Golev 2015)

Urban mines consist of a complex amalgamation of valuable materials as well as some hazardous materials and substances. Hazardous substances such as heavy metals (mercury, lead, cadmium) and chemicals (ozone depleting substances or flame retardants) complicate reutilization (UNU 2014, 50-51).

Innovation in Practice

Researchers at VTT, the Technical Research Centre of Finland, have developed a biological fungi filter that could recover up to 80% of gold from e-waste (Happich 2014). A British initiative, Clever, proposes the use of cellulose for circuit boards and for precious metals extraction applying enzymes (Urban Mining 2014).

Another inspiring example is one from the French company Veolia Environment of extracting rare earth metals (such as platinum) by sweeping the streets of London. According to Veolia, the yearly value gained from UK streets is about $123 million and a considerable amount of rare elements could be recovered each year; more specifically about 1.5 tonnes of platinum, 1.3 tonnes of palladium, and 0.8 tonnes of rhodium. (Taneja 2015)

Conclusions

Urban mining sustainably develops our society. Urban mining is a smart resource management solution. A prerequisite for efficient technosphere mining requires a careful mining plan and strategic data cataloguing. Understanding location, size, concentration and availability of materials stocks and flows support a systematic coherent collection and secondary resource redistribution system.

Design thinking further facilitates the recapturing of complex materials embedded in our urban infrastructure. Support policies and incentives play important roles in the transformation towards more sustainable life. Finally, human safety and environmental responsibility need to be maintained during the urban mining process.

Together with smart consumption, urban mining plays a key role in the economic opportunities presented in the circular economy framework.

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3.1 Co-authorship

The author was the principal writer of the Article 2 and was supervised by the co-writer, Dr. Brett Fifield.

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4 ARTICLE 3 - CIRCULAR DESIGN - DESIGN FOR CIRCULAR ECONOMY

Katerina Medkova and Brett Fifield

Background

Economic growth, in our linear economy, is measured by gross domestic product, in other words the growth in throughput or the value of products and services produced. This pattern creates the consumer society, which assumes an abundance of resources and shapes behaviour around accumulation of stuff. This accumulation of stuff is manifested in three forms: non-reparability, functional obsolescence and the power of marketing. As societies attempt to mirror the lifestyles advertised in media, they fuel the unsustainable demand for new and improved products.

The linear-structure design focuses on the product itself and how it is packed (Aho 2016). The cheap and readily available resources and a hunger to produce and sell more and more products have made manufacturers as well as consumers blind to what happens with the products after they break down or become obsolete. Sometimes, planned obsolescence has been built in, even for products that could have lasted longer, in order to make space for brand new ones.

Traditionally, design has not considered product impact during its birth and use, and what happens when it is not in use anymore and thrown away. Products were not designed to last, allowing for new models to fulfil the needs and temptations of consumers. The emphasis was laid on product aesthetics and attractiveness, and brand promotion by applying smart marketing (Brown 2008). As a result, our consumer society has been actively seduced by new and better goods and services, leading to massive resource consumption and waste.

Pervasive seduction marketing and even cultural norms compel us to buy more and more products that we do not really need. When the product breaks down, it is either financially not viable to repair it, or it is simply nonreparable. Innovation and technology development make us buy new models, as it is almost impossible to upgrade a product. As a result, huge quantities of goods end up in landfills, creating detrimental environmental consequences with enormous loss of materials, energy, water and labour embedded in them. As Sophie Thomas, a director of Circular Economy in RSA (Royal Society for the Encouragement of Arts, Manufactures and Commerce), stated, 'We are convinced that waste is a design flaw.' (RSA 2014, 9).

Having more 'sustainable' products, partially made of recycled materials, or being more energy-efficient than their previous versions, is not enough (Hunter 2016). For instance, Bakker et al. (2014) indicates that even though the energy consumption of the products studied (laptops and refrigerators) has been reduced considerably, their life cycle has been counterbalanced and, therefore, the overall environmental impact is negative (Bakker, Wang, Huisman & Hollander 2014, 13).

Circular Design

Design in the circular economy is complex and requires a transformation in thinking, to shift 'from the current product-centric focus towards a more system-based design approach' (RSA 2014). Circular design searches for a way to deliver a product or a service that is functional and made of optimum materials to deliver the best performance while minimizing its negative impact along the whole life cycle. (Aho 2016)

Circular design challenges a generation of products and materials in a way that minimizes the use of primary raw materials. As the name implies, the focus of circular design is on curtailing the value loss embedded in these products and materials, by keeping them circulating in closed loops. These loops, such as reuse, repair, remanufacture, refurbishment or recycling, extend the product's life cycle and improve resource productivity. At the end of the life, inspired by nature, a product, its part, or a material will become a resource within or even outside of the original application. Components could be reclaimed for remanufacturing. Materials can continue their life through recycling. The circular economy applies a combination of these strategies with a preference to the activities closer to the user or consumer, in other words, as in the inner loops of the diagram in Figure 7. (Acaroglu 2010)

The key lies in how a product or a material is designed and how different aspects and requirements are balanced. The design phase influences the product's life and the ease of its reprocessing. Designers have the opportunity to consider the durability, compatibility, modularity or multi-tasking functions of the designed products. However, this does not rest solely on designers' shoulders (RSA 2014, 43).

Both circular design and sustainable design focus on environmental, economic and social aspects. However, they differ significantly in how the goals are attained. The latter puts a product, value preservation, and its eco-impact on the planet into the central role. On the other hand, circular design commences with the optimization of the resources' economic potential through new business models. At the same time, emphasis is on resource restoration and quality of life. (Circular Product Design 2016)

New Business Models

A project called The Products That Last, led by the Industrial Design Engineering Faculty of the Delft University of Technology, focused on discovering new business opportunities, models, and design strategies for the circular economy.

'Every new product development effort should be coupled with the development of a business model which defines its 'go to market' and 'capturing value' strategies.' (Teece 2010, 183). The Products That Last project names five business model strategies to help businesses and designers in a thinking shift towards a circular economy. (Bakker & Hollander 2013; Bakker et al. 2014)

There are five business models for long-lasting products. The (1) **classic long-life model** focuses on the sale of high-quality long-life products. The

(2) **hybrid model** combines durable products, designed to be easily disassembled, with short-life and fast-cycling, repeatedly sold consumables. The (3) **gap-exploiter model** uses the leftover value in products or components that are still functional, broken or discarded and resells repaired or refurbished products, components or services. The (4) **access model** provides access to a product rather than its ownership. The (5) **performance model** provides product performance rather than the product itself. Products are designed for easy maintenance, durability, and long life. (Bakker & Hollander 2013, Bakker et al. 2014) The last two models listed above provide capability and services to a user without physical ownership (Bocken et al. 2016).

Similarly, Bocken et al. (2016) discuss six potential business models for a circular economy: (1) **access and performance**; (2) **extending product value** through life extension strategies, which is similar to the gap-exploiter model; (3) **classic long life**; an extra model, (4) **encouraging sufficiency** through principles, for instance, products' durability, upgradability, and non-consumerist approach to sales; (5) **extending resource value**, which is also similar to the gap-exploiter model; and (6) **industrial symbiosis**, a process-oriented solution, which uses residual output to become a feedstock for other processes.

Strategies for Circular Product Design

Based on the Products That Last research, six strategies for Circular Product Design were identified (Figure 5), indicating an impact on product integrity. The aim of these strategies is to counter obsolescence and keep a product as close as possible to its original purpose.

1. **Design for Product Attachment and Trust**, sometimes called 'design for emotional durability', is regarded as the most challenging strategy. It aims at responding to an emotional obsolescence by creating long lasting products that people will love and trust. (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016)

2. **Design for Product Durability** creates products resistant to wear and tear, in other words, physically durable products. Here, the material choice is crucial in overcoming functional obsolescence. (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016)

3. **Design for Standardization and Compatibility** fights against systemic obsolescence by designing product parts and interfaces suitable for other products and aims at multi-functionality and modularity (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

4. **Design for Ease of Maintenance and Repair** counters functional obsolescence by ease of maintenance to keep a product in working condition, and non-challenging reparability and replacement of broken parts to extend the end of the life (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

5. **Design for Upgradability and Adaptability** avoids systemic obsolescence by maintaining product usability for a long time by upgrading its value and performance, and at the same time, by adaptation and modification towards the changing needs of a user (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016).

6. **Design for Disassembly and Reassembly** also avoids systemic obsolescence by designing products and their parts to be eventually easily separated and reassembled. This strategy has a big impact on component and material reuse and remanufacturing. (Bakker & Hollander 2013; Bakker et al. 2014; Circular Economy 2015; Bocken et al. 2016)

Figure 5: Six Design Strategies for Longer Lasting Products (Circular Economy 2015)

In addition, Bocken et al. (2016, 310) propose **Design for Reliability**, which relates to products designed with a high prospect of no-failure operation through a certain time if the manufacturer's use and maintenance instructions are observed. Also, **Design to Dematerialize,** reducing the amount of materials required but still sustaining the core functionality, should be taken into account. Dematerialization also means inventing brand new solutions with no or less material required.

Practical Examples

Clocks are available everywhere, for instance in our smartphones or computers, and still we wear watches on our wrists. Classic watches are typical examples of design for attachment and trust. They are of high quality and last long (Design for Durability) and thanks to a stylish classic look can be inherited from generation to generation. Miele, a manufacturer of high-end domestic appliances, is well known for its long lasting and durable products. Both of the design strategies are also reflected in a product called My Paper Bag, made of ecological tanned leather with a wooden bottom in a Fair Trade workshop in India. The bag has a classic look, is durable and the leather appearance becomes even more attractive over the years. The same could be applied to the original Swiss army knives from Victorinox or cast iron pots and pans from le Creuset. The Gaggia Classic home-use espresso machine has not changed its design since the 70’s. It is durable, high-quality and offers online guides for maintenance, repair and upgrade.

Bugaboo Cameleon is a high-quality multifunctional baby carriage adaptable to every age (from newborns to toddlers) and the type of surface it is used on (Design for Upgradability and Adaptability). It is durable and long lasting (at least 15 years - Design for Durability). Bugaboo Cameleon is easily adjustable and transformable. Different colours and many accessories are available (Design for Product Attachment and Trust).

A combination of all the above-mentioned design strategies is applied in Google's project Ara. It is a customized, modular mobile phone with swappable parts: a high-resolution camera, a louder speaker or a better battery (Design for Attachment and Trust, Durability, Standardization and Compatibility, Ease of Maintenance and Repair, and for Dis- and Reassembly). During the designing stage, a free space for new functions and applications that do not yet exist is reserved to overcome systemic obsolescence (Design for Adaptability and Upgradability).

All the above-mentioned examples represent the classic long-life business model.

The Reef NWS sustainable sandals are made from non-toxic materials and glues with minimum material use in mind (Attachment and Trust). The smart puzzle-like cut enables to minimize the waste to less than 1% and allows the production of seven more pairs of shoes per yard of fabric. For instance, the stitching, logo, threads and upper-liner are made of 100% recycled water bottles (PET). The footbed contains 51% post-industrial recycled ethylene vinyl acetate (EVA), whereas the common producers’ standard is only 31% EVA. The smart design of the sole mould reduces waste by 20%. Also, Freitag bags and accessories are made from used products and materials, such as truck tarps, car seat belts, air bags and bicycle inner tubes. This makes their products unique (Attachment and Trust) and durable due to tear resistant and waterproof materials. Both cases give used material a new life in a different product and thus represent the gap-exploiter model.

gDiapers combine long lasting breathable gPants together with short-lifespan disposable inserts, representing the hybrid business model. These 75% cellulose-based inserts are flushable and compostable (only the wet ones) and Cradle to Cradle Certified™ Silver (Attachment and Trust).

Sandwichbike' s bicycles consist of a durable frame made from four weather-coated plywood plates (PEFC certified) and aluminium cylinders that squeeze the other necessary components into a sandwich-like structure. The eco-friendly and eye-catching product is delivered in a flat cardboard box and easily assembled by the customer (Product Attachment and Trust, Product Dis- & Reassembly). All necessary tools are included. In addition, the different parts of the bike can be interchanged across different models (Product Standardization & Compatibility).

Examples of the access model could be public bicycles, online access to accommodation (Airbnb), cars (Zipcar, Greenwheels, Car2Go), or movies (Netflix) and music (Spotify). The representatives of the performance model are, for instance, Phillips selling lighting service via their Pay per Lux system, Michelin selling kilometres, not tyres, and Rolls Royce's leasing programme for aircraft engines.

Tools and Methodology for Designers

Circular economy emphasizes the importance of cooperation and collaboration across various fields; producers, suppliers, remanufacturers, logistic and recovery managers, users/consumers, academia, scholars, policy makers, and researchers and developers. Especially in the design phase, active communication between designers, material experts and engineers, environmentalists and economists, and end users is essential for innovative circular design decisions. (Aho 2016; Medkova 2015, RSA 2014)

RSA (2013, 2014) created a tool for designers, the Circular Network Diagram (Figure 6), in which they mapped different stakeholders engaged during a product’s life cycle that should be involved in the dialogue on changing design towards circularity. The Circular Network Diagram divides these players into segments of a circle, which emphasizes the equality and importance of all stakeholders’ collective views and insights. These general segments are: consumers and users, design, academics and education, investors, policy makers, resource management, material experts, manufacturers, and finally brands and companies. The segments are then split into more detailed sub-segments. (RSA 2013, 2014)

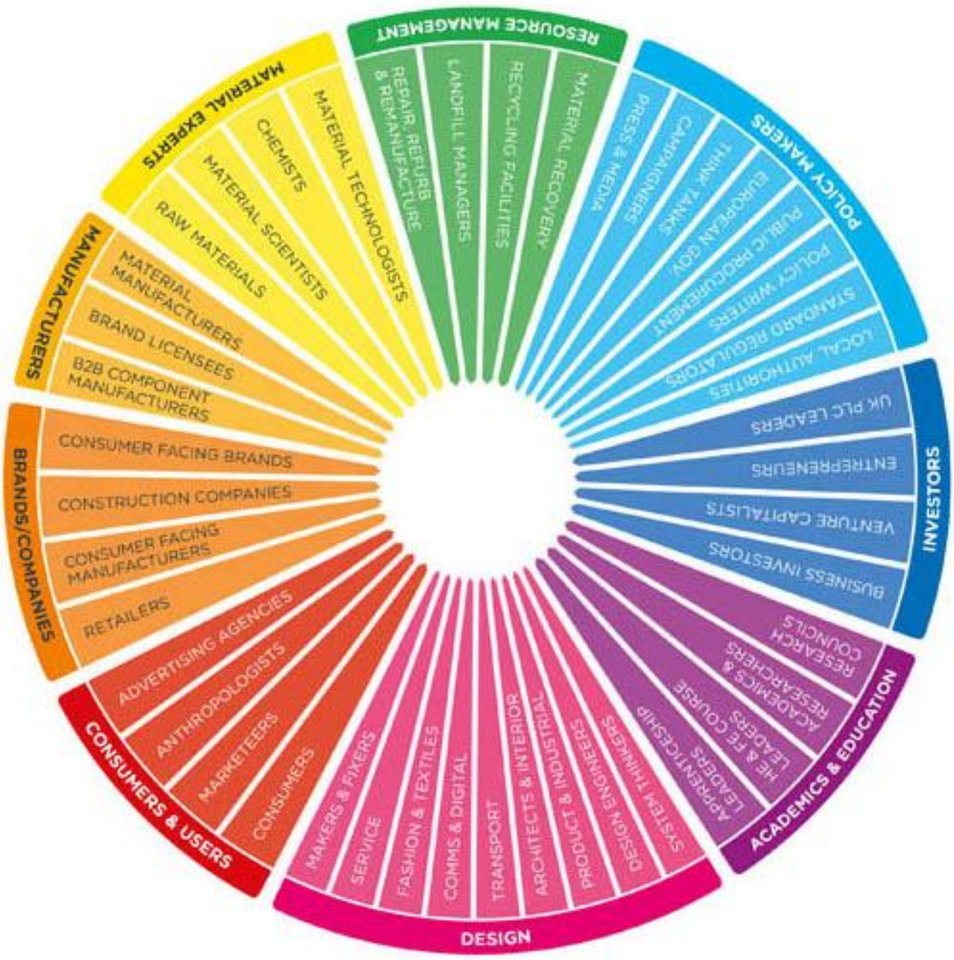

Figure 6: The Circular Network Diagram (RSA 2014)

Most of the current solutions predominantly focus on “end-of-pipe” solutions, such as recycling, which more accurately might be referred to as downcycling and major loss of embedded value. The resource challenge should not be approached from the end. Instead, we have to start at the beginning of the life cycle of the product, component or material, before it is physically born, during the design phase. (Medkova 2015, 68) Also, Hatcher et al. (2011) recognize that the product’s impacts and costs during its lifespan and during reprocessing at the end of life are determined during the design stage.

To reiterate the earlier findings, ‘Product design is the starting point of the resource challenge’ (Medkova 2016, 68) for creating a sustainable and systematic approach to reconfigure our resource dependency while supporting well-being and economic growth.

According to The Great Recovery research, conducted by the Royal Society for the Encouragement of Arts, Manufacturers and Commerce (RSA), four models can be distinguished for circular design: design for longevity, design for leasing or service, design for re-use in manufacture, and design for material recovery. The circular economy principles are expressed in the Four Design Models diagram in Figure 7, where the loops closer to the user are the most powerful. Also, the model enables designers to understand who possesses the key knowledge in all four loops. (RSA 2014)

Design for Longevity promotes long-life and reliable products that can be easily dismantled for upgrade or repair by the user. Security seals or glued components should be avoided in order to avoid possible warranty loss or component breakage. Open-source manuals, reasonably priced spare parts, and services should be available.

This all leads to a relationship development with the user and his quality association with a product that lasts and thus brings an emotional value to the consumer to use it longer or pass it on to somebody else rather than simply dump it. (RSA 2013; Cabo 2015)

Not everything should be designed for longevity. There is a wide spectrum of products with a different length of life cycle: short, medium and long. A very short life cycle should be predetermined for food packaging and it should be biodegradable or easily recycled. A medium long life cycle can be seen in electronics, which can be easily repaired and upgraded to extend the life cycle. And finally, products meant for a long life cycle, such as pots and pans, furniture, and jewelry should be durable not only physically but stylistically as well. (Acaroglu 2010)

Design for Leasing/Service changes product ownership into a product as a service business model. As the product and, therefore, the material ownership stays with the producer or manufacturer, the designed products are durable and long lasting in order to maximize efficiency. The value in the product is therefore kept within the system. Product as a service can provide more users with high-tech products and higher specifications of design, which would normally be out of reach for them. (RSA 2013; Cabo 2015)

Another way could be selling an outcome. An example of this is ProjectBox, a package of quality professional tools, materials, and detailed instructions on how to complete a required job. Purchasing cheap, one-time-used tools can be avoided, and time and resources are saved. When the job is done, the ProjectBox is collected, together with the waste and unused materials. (The Agency of Design 2016 b)

Design for Re-use in Manufacture aims at the return of old products or their components back to manufacturers for replacing faulty or obsolete parts, to be subsequently resold. These products are designed for longevity and easy disassembly on a manufacturing scale, in order not to waste the value embedded. The key enablers are reverse supply chain management and supporting legislation. (RSA 2013; Cabo 2015)

According to Bakker et al. (2014), it is essential for designers to attain a deep knowledge of ‘how the product and its parts wear and tear, and of how to decide which parts should last, and which should be replaced, and when’ if the product is expected to be refurbished several times during its life cycle. Many aspects ought to be considered: the functionality, appearance, and costs. (Bakker, Wang, Huisman & Hollander 2014)

Easy non-destructive and quick disassembly can be attained, for instance, by placing a small pellet next to a snap-fit joint. Using a vacuum, the pellets expand and open the snap fits, and thus disassembly of a product with high-quality material reprocessing and recovery is possible. (The Agency of Design 2016a)

Despite the significant economic, environmental and employment benefits, remanufacturing continues to be undervalued and under-recognised, reveals the recent Remanufacturing Market Study (2015), sponsored under Horizon 2020. In Europe, knowledge transfer across industrial sectors is missing, both for remanufacturing and recycling (Remanufacturing Market Study 2015, 10).

Design for Material Recovery recaptures materials and products to be reprocessed and recycled into new materials. This involves components that cannot be repaired or upgraded but also fast-flowing products and materials such as packaging.

Using single rather than complex materials and avoiding toxic materials increases recyclability. Also, developing accreditation systems for secondary materials will boost the confidence of the designers, manufacturers and consumers. (RSA 2013; Cabo 2015)

The below-mentioned tool (Figure 7) serves only as a guideline for designers, as no one-fits-all solution for designing circular products exists. Different life extension and repurposing strategies are needed for different product characteristics, such as resource intensity, life expectancy or technological and style maturity, and business limitations, such as legislation or market dynamics (Bakker, Wang, Huisman & Hollander 2014).

Figure 7: The Four Design Models (The Great Recovery 2013)

Various methods, indicators, and tools can guide the designers or companies in their decisions. So far, these measurements have indicated only specific business drivers or were designed for linear operations. According to the Circularity Indicators Project (2015) of the Ellen MacArthur Foundation (EMF), no circular economy metrics exist. (Circularity Indicators 2015a, 2015b, 2016) A complex methodology providing the systems thinking still needs to be developed.

Life Cycle Assessment (LCA) and Cradle to Cradle (C2C) only partly indicate circularity and exclude material criticality, as seen in Figure 8. The LCA tool evaluates environmental aspects and impacts of a product or a service during its entire life cycle. C2C is a framework of biological and technical nutrient cycling and it aims at eco-effective, waste-free production.

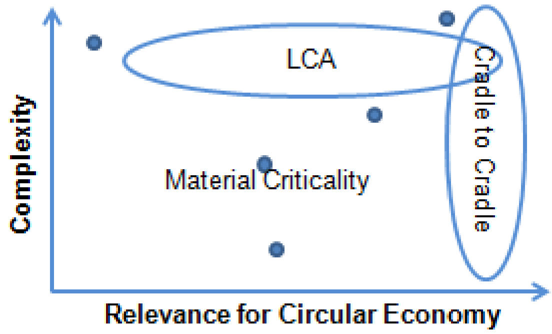

Figure 8: Stakeholder Perception of Existing Indicators (Circularity Indicators 2016, 7)

In 2015, Circularity Indicators (CI) methodology and a web-based tool were developed by EMF, together with Granta Design, and co-funded by the European Union, to measure a company's 'linear to circular' transition progress. The CI tool only deals with technical cycles and non-renewable materials. The focus is on the material flow restoration level of products or companies. Circular Indicators are particularly intended for product designers to guide their decision making, and can serve internal and external company reporting, procurement and investment purposes as well. (Circularity Indicators 2015a, 2015b)

Circular Indicators consist of the main Material Circularity Indicator (MCI) and optional complementary indicators for additional insights: complementary risk indicators (material price variation, material supply chain risks, material scarcity and toxicity) and complementary impact indicators (energy usage, economic benefits, or CO_2 emissions). The results obtained from the MCI range between zero and one; low values show linear flows and the maximum value of one represents fully circular flow. (Circularity Indicators 2015a, 2015b) The LCA and MCI could be combined as many of their input data are identical (Circularity Indicators 2015b, 11).

The success of circular design or circular economy in general depends on transforming the whole system and redesigning our thinking and, ultimately, the collecting and return systems. The same importance should be paid to establishing of infrastructure for various rejuvenating processes (repair, rebuild, recycle, etc.), and the exchange of information and knowledge via active dialogue between various stakeholders to spark innovation. By creating ongoing and circulating material and information flows, a product, a component or a material will get to the right and most value-saving player in the system at the time, in order to extend product life or give it a second or multiple life cycles. Changes in technology, products and markets are dynamic, and so should be the circular design strategies, policies, and processes (Bakker, Wang, Huisman & Hollander 2014).

Education

The shift towards a circular economy is associated with a change in our attitudes, mindsets, perceptions and behaviour. It requires a change in the way of thinking and acting, going towards sharing and collaborating. Educational institutions are responsible for implementing circular economy principles into their curricula and developing the required new skills and competencies. Based on the RSA (2014) study, action-based learning is recommended, including teardown workshops and various supply chain site visits (RSA 2014, 41).

Cross-disciplinary education can be beneficial as it encourages people to see world views from a different angle. At the same time, it helps people understand complexity and systems thinking. (Martin et al. 2007) Multi-disciplinary education not only broadens designers' knowledge of other fields, it also offers them an opportunity to practice communication and problem-solving strategies with non-design students. This will be essential when dealing with colleagues and clients from different backgrounds in the future. (Design Council 2010)

New competencies, knowledge and working methods for core areas of functional circular design need to be developed. According to the EMF, these areas include 'material selection, standardized components, designed-to-last products, design for easy end-of-life sorting, separation or reuse of products and materials, and design-for-manufacturing criteria that take into account possible useful applications of by-products and wastes’. (Ellen MacArthur Foundation 2015)

Circular Economy Design Concept

Based on the literature research, a Circular Economy Design Concept is depicted in Figure 9. Circular economy design is the engine of the circular economy. The vehicle for changes is Redesign. Redesign occurs by focusing on the four lines of discussions (Systems Thinking, Awareness, Mental Shift, and Communication) around the four elements (Circular Design Strategies, New Business Models, Cross-disciplinary Intelligence, and System Conditions).

The three dimensions of People, Planet, and Profit both drive and are driven by circular design and influence the redesign processes in the circular economy. In Figure 9, the overall mutual impact of circular economy design on the three dimensions of People, Planet and Profit is emphasized by the bidirectional drivers. Also, these three dimensions are symbiotic, because changing one dimension has a direct impact on the other two dimensions. Not only does the circular design have an impact on the social, environmental and economic aspects of the circular economy, but People, Planet and Profit influence the design at the same time. Continuous redesigning enhances the understanding and appreciation of the four elements.

The first (1) element, Circular Design Strategies, consists of various life-extension strategies. It aims at designing long-lasting and durable products that are easily maintained and repairable, upgradable on a modular basis, and standardized. It ensures easy dis- and reassembly, and product structure adaptability.

New Business Models (2) are closely bound to Circular Design Strategies. These models focus on long lasting products offered as services or sharing platforms, enabling a product access or performance, rather than its ownership. As the focus of the main producers and manufacturers is not on volume anymore, additional revenues are generated from additional services offered along the entire product life cycle to counteract the drops. The aim of the new business models is to retain products, components, or materials of the highest utility and value. It includes easy maintenance, cost-effective repair, refurbishment, and remanufacturing. Additionally, reselling and remarketing of used products are included, as the first user is not meant to be the last one. The re-commerce and value recapturing activities require a functional take-back system and reverse logistics. The supply chain is no more one-way only, but it includes both directions: to the market and from the market.

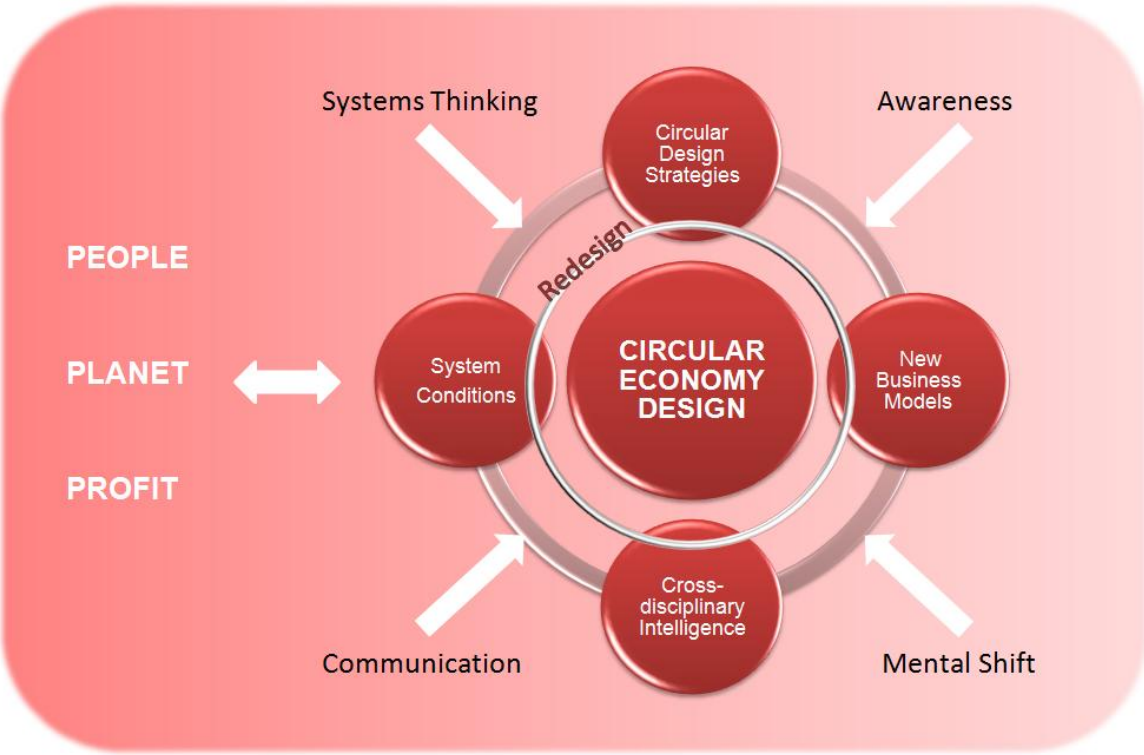

Figure 9: Circular Economy Design Concept

Systems Thinking is vital for the circular economy concept. As Joël de Rosnay (1979) proposed, the world should not be looked at through a microscope, to see all the details, nor through a telescope, to see the distance, but through a new tool, a macroscope. The macroscope is a symbolic tool made of various methods and techniques that diminishes details but observes the big picture and magnifies what links things together. ‘The roles are reversed: it is no longer the biologist who observes a living cell through a microscope; it is the cell itself that observes in the macroscope the organism that shelters it.‘ (Rosnay 1979) In order to think in systems, Cross-disciplinary Intelligence (3) is necessary. As the name implies, the intelligence comes from various sectors, industries, and players, and can be obtained through cooperation, collaboration and new partnerships. Furthermore, it involves mapping and evaluation of various aspects: social, environmental, economical, cultural, emotional, physical, and technological. Looking at the systems holistically is a prerequisite for a functional circular design and economy.

The fourth element, System Conditions (4), empowers an environment that supports circular economy. Just to name a few, sector-specific legislation, incentives, mandatory and voluntary programs, financial instruments to spur technological innovation and R&D, functional infrastructure, and information and material flows encourage the adoption of circular business models. Policy measures can raise consumers’ and producers’ awareness of circular economy practices and products and advocate the importance of repairability and durability. Development of corresponding assessment tools and methods, and quality standards, helps the transition towards a circular economy. Moreover, new skills and expertise are needed for these new ways of thinking, working, valuing, and new lifestyles. As the circular economy is a dynamic and developing concept, circular design reflects this evolution by continuous redesigning and system innovation. For that, a constructive debate and information sharing amongst relevant stakeholders must be facilitated. Also, the circular economy drivers, reasons, benefits, and challenges need to be communicated, in order to raise the awareness and importance of this topic. Only then can a mental shift and attitude change take place.

Conclusions

Design for a circular economy combines leveraging of the four main elements (Circular Design Strategies, New Business Models, Cross-disciplinary Intelligence, and System Conditions) with the four lines of discussion. By focusing on redesigning processes, the lines of discussion reflect the reprioritization of our choices. Circular design thinking is not a marketing buzzword. Circular design takes into consideration People, Planet and Profit, and is embedded as a core strategy for businesses and consumers.

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4.1 Co-authorship

The author was the principal writer of the Article 3 and was supervised by the co-writer, Dr. Brett Fifield.

4.2 Publication Status, Citation

Article 3 has been accepted for publishing in the Lahti Cleantech Annual Review 2016. It will be published at the turn of the year 2016 as a publication series of Lahti University of Applied Sciences.

For citation purposes, please use the following format:

Medkova, K. & Fifield, B. 2016. Circular Design – Design for Circular Economy. In Cura, K. & Virtanen, M. (ed.) Lahti Cleantech Annual Review 2016, Lahti: Lahti University of Applied Sciences

Also, Article 3 was accepted for presentation at the Thirty-Second International Conference on Solid Waste Technology and Management in March 2017 in Philadelphia, Pennsylvania, USA. The acceptance letter is attached in Appendix 2 of this thesis.

5 CONCLUSIONS

In this chapter, the author aims to reflect on knowledge and insights gained during the thesis process and finally the author concludes the findings.

5.1 Reflections & Discussions

The author has gained a lot of rare insights around the topic. It has reassured the author about the complexity and mutual interdependency and impact of all the individual pieces of the circular economy puzzle. Having all of these puzzle pieces in place enables us to see the whole picture. It is a long and challenging journey ahead of us and there is still a lot that needs to be and will be discovered.

While writing the thesis and the articles, the author has realized that one of the most powerful enablers of the transition is information technology (IT); digitalization, smart devices, technological advances, Internet of Things (IoT), cloud computing, etc. Should a fourth article be added to this trilogy, IT and digitalization would be a consequent choice. The fast evolving digital revolution can provide us with information needed for closing the material loops. If the design is the heart of circular economy, then the IT industry is its backbone.

Digitalization reshapes our economy, and based on the Ellen MacArthur Foundation report called Intelligent Assets (2016), it is expected there will be almost 50 billion connected intelligent devices by 2020. These intelligent assets provide information sets, which are essential for circular economy and design, through the Internet of Things network. The flow of materials with encoded intelligence transforms into valuable information flow, for instance, location and condition tracking for reverse logistics. This access and traceability are a prerequisite for keeping materials and products optimally circulating with resource efficiency and maximum value preservation in mind. IoT can help us unlock the environmental, economic and social potential of circular economy and provide well-being and growth through effective use of resources. At the same time, it invites to innovation and myriad opportunities.

The increasing use of IoT calls for security innovations to protect privacy, ownership, intellectual property and generate trust. Capturing the possibilities of the digital world, an open and global payment protocol needs to be established. Blockchain technology with its cryptocurrency, Bitcoin or similar, can be a solution to a new way of a digital capital flow excluding intermediary. By incorporating referenceable data into transactions, true transparency and unconflictness can be created. Moreover, blockchain can increase the efficiency of supply chains. (Intelligent Assets 2016)

5.2 Future Studies

The author suggests the impact of digitalization and use and application of Internet of Things (IoT) should be explored. It is beyond doubt that they are indispensable enablers of circular economy. Furthermore, the topic of blockchain is worth examination.

Also, more case studies and a documentation of circularity progress across different sectors and industries could motivate many to make a change.

5.3 Author’s Contribution

The author elaborated an up-to-date concept which, regardless of its infancy, is very relevant to our society. By deepening the lines of discussions, new proposals, and theoretical concepts were created (Figure 4 and 9), contributing to a better understanding and extending the knowledge bases of the phenomena.

Besides the articles, several lectures and presentations about circular economy, conducted by the author during 2015 and 2016 for Lahti UAS students, have contributed to awareness and the increase of positive attention.

5.4 Conclusions & Recommendations

Circular economy is a compelling concept. In order to make the system work, we should not try to ‘fix’ our massive material consumption and waste creation by introducing end-of-pipe solutions. The desire is to move from ‘less bad’ to ‘more good’ innovative breakthroughs. Most importantly, we have to look at the beginning of the whole process, the design phase, before any product will see the light of day. Circular design emerges as a key factor to become a more resource savvy. Design thinking helps to optimize yields by circulating resources at their highest utility and value at all times. Circular economy and design embrace circularity in a new circular fashion by reinventing and reimagining our current ways of doing and valuing things. By redeploying already mined and manufactured resources from urban mines and looping them back in the system, already exploited natural capital can be preserved and regenerated again, and steps towards the balance between economy and nature can be reached.

Circular economy should be regarded as a novel value creator, a resource preserver, and a global challenges solver. It demands a novel collaborative mechanism engaging companies, governments, academia and consumers based on an active dialogue and sharing knowledge. It requires a change in attitudes and setting up new circular norms and manners. Complementary economic and financial instruments are necessary to create a supportive innovative environment, push change in thinking, and stimulate greater circularity within the system.

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APPENDICES

APPENDIX 1 – Examples of Circular Economy in Practice

The Invention of Velcro – Inspired by Nature

Velcro is the best known and most commercially successful instance of biomimicry. Biomimicry is innovation inspired by nature; it helps us to solve human challenges by mimicking the nature. (Invention of Velcro 2016)

Figure 10: Velcro (Stocksnapper Shutterstock)

Velcro (Figure 10) was invented by a Swiss engineer, George de Mestral, in 1941. He got inspired while removing Burdock Burrs (Figure 11) from his clothes and a dog after hunting in mountains. After a closer look, he has discovered the individual needles of burrs to be curved at their end into a hook-like shape. These hooks are then easily caught on loops of clothes or hairs. Velcro has been patented in 1955. Velcro has gained popularity especially after NASA's application of Velcro on their space suits. (Invention of Velcro 2016)

Figure 11: Burdock Burrs (Print Magazine)

Tesla and SolarCity - Announcing Powerwall 2 and the Solar Roof

The amount of energy the sun can supply us within an hour can cover the need of the entire planet for a year (Tesla 2016).

Tesla together with SolarCity introduced durable and long-lasting Solar Roof tiles (Figure 12), in which three main aspects were combined: powerful, beautiful, and affordable. Tesla claims, that a Solar Roof together with projected utility bill savings is cheaper than a roof made of traditional materials. Above all, the solar roof can provide homes with clean and renewable energy and the unique appearance of the tiles complement the house. The special design of the solar tiles and its integration into the roof make them not visible to the eye, therefore they resemble a traditional roof. (Tesla 2016)

Figure 12: Solar Roof Tiles by Tesla (Tesla 2016)

These tiles are made of tempered glass and therefore are very durable and long-lasting. According to Elon Musk, Tesla’s CEO and chairman of SolarCity, the lifespan of minimum 50 years is expected and it offers 98% efficiency in comparison with traditional photovoltaic panels, which needs to be mounted on top of the roof. (Stevens 2016)

To be able to store the solar energy and turn it into electricity, a double the energy than first generation battery, powerful and compact Powerwall 2 residential home battery has been unveiled as well (Figure 13) (Stevens 2016, Tesla 2016).

Figure 13: Powerwall 2 (Tesla 2016)

According to Musk, if Solar Roof is used together with the Powerwall 2 battery, there is no need to get any power from the electricity grid (Stevens 2016).

Tesla and SolarCity offer a unique renewable system of transforming the endless sun energy into electricity, which can be then deposit in an electric car and stored for later use in the Powerwall battery (Stevens 2016).

Mushroom Production on Coffee Waste - The Blue Economy

The Blue Economy brings into balance people, economy and nature by cascading locally available resource, so that 'the waste of one product becomes the input to create a new cash flow'. (Blue Economy 2016)

We use only 0.2% from the amount of coffee beans needed to prepare a cup of coffee. The rest is a waste, which is not used. However, it has been found out that this organic coffee waste creates a suitable environment for cultivating mushrooms (Figure 14). After harvesting, the coffee ground and mushroom leftovers are a great source of protein for worms, which can be used for feeding fish. Fish digest the worms and create nutrients for water plants. Also, warms transform the leftovers into a fertilizer for plants or it can be used as animal feed, such as for pigs and cows. Animals turn this feed into manure, out of which a biogas and a fertilizer can be produced. During the biogas production, a heat is created and collected for drying the remains for fertilizer or heating water for housing. This nutrient cascading chain can continue more and more. The single coffee ground waste can supply us with food and energy, and it creates new jobs, locally. This is a functional and sustainable example of the Blue Economy, using efficiently local resources, creating job and social capital, fight hunger and poverty, and offering new business opportunities, while preserving the environment. (The Blue Economy 2015, Blue Economy 2016)

Figure 14: Mushroom Cultivation on Coffee Waste (Blue Economy)

APPENDIX 2 – Acceptance Letter

The Journal of Solid Waste Technology and Management

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THE THIRTY-SECOND INTERNATIONAL CONFERENCE ON SOLID WASTE TECHNOLOGY AND MANAGEMENT
Philadelphia, PA U.S.A. March 19-22, 2017

November 10, 2016

MSc. Katerina Medkova
Student
Lahti University of Applied Sciences
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Finland

Dear MSc. Medkova:

Thank you for submitting the paper, "Circular Design - Design for Circular Economy," by Katerina Medkova with Brett Fifield to *The Thirty-Second International Conference on Solid Waste Technology and Management*. I am pleased to inform you that this paper has been accepted for oral presentation at the Conference.

ICSW 2017 is designed to be an enjoyable and informative conference for participants. The Information for Speakers web page gives details of the presentations, conference proceedings and fees. It also links to forms that must be completed and submitted by the indicated dates.

You may want to examine the agenda from the 2016 conference at solid-waste.org to become familiar with the general structure of the conference.

If you have any questions or concerns, please contact me as soon as possible.

I look forward to your presentation at the Conference.

Very truly yours,

Ronald L. Mersky, Ph.D., P.E.
Conference Chair