Towards Circular Economy in Manufacturing: Identification of Barriers Seen by Norwegian Manufacturing Companies

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Abstract
Most companies include in their strategy, a commitment for sustainable growth which involves a switch towards a circular economy (CE). A CE transition is hindered by barriers that must be overcome to comply with sustainable growth. In this paper we identify barriers faced by industries, and we propose solutions for how to overcome these barriers. The main barriers were found to be complexities in supply chain, coordination problems, quality issues, little attention to CE in production and design, difficulties in disassembly of products and high start-up costs. To overcome these barriers, we present a model supporting life cycle information.

Keywords: Circular Economy, Sustainability, Barriers

Introduction
While globalisation gives both a larger market and an increased competition, the companies` supply chains have become more complex and critical than before (Majta 2012, Sheffi 2018). The worldwide consumption has increased over the last decades and it is expected that the resource use globally would increase three times more by 2050 (Lucas 2014). The effect of population growth and the following increase in consumption raise challenges to the environment, the overall society, and the depletion of scarce resources (Ellen MacArthur Foundation 2015). The resource consumption of the linear model follows the take-make-consume-dispose pattern which is not sustainable as its over-use scarce resources and contribute to pollution of the environment. The cities are generating 1.3 billion tons of waste each year and it will surge to 2.2 billion tonnes by 2025 (Masi et al., 2017). Waste and trash have a negative impact, our oceans are accumulated with plastics, marine life in endangered, animal kingdom and wildlife are affected by too many pollutants, persistent chemicals are causing diseases, depletion of

the ozone layer, global warming and trash landfills which have led to serious actions against waste. The electronic waste is another kind of waste that is increasing fast.
Businesses in need to satisfy their customers, must increase the prices of the materials due to the increasing scarcity of resources, which again might affect the progress and profitability of the companies in a negative way unless it is addressed. More pressure of environmental concern from customers are seen to result in more eco-friendly products. The CE model is based on the concept of changing the take-make-use-dispose pattern into closed-loops of material flows through processes such as maintenance, repair, reusing, refurbishing, remanufacturing and recycling (Masi et al., 2017). Supply chains are considered to be an important factor for implementation of the CE model because of the need for a joint effort of suppliers, manufacturers and customers. The co-operation and co-ordination between supply chain upstream and downstream partners are essential as upstream partners obtain eco-friendly inputs cooperating with downstream partners for environmental management practices such as product return, reuse and recycling (Zhu et al., 2010).

The transition to CE is not as easy as is evident from several studies that have identified many barriers. Due to these barriers, firms are slow to make a transition towards the CE (Masi et al., 2017; Preston, 2012). We claim that the transition to CE is only possible through the better management of information and the informational flow. We follow Rosén (2010) in defining the information needed for a product as "*all the information required in making decisions and taking actions in the whole life cycle of a product*". Information technology is considered as a priority for managing the information flow across the supply chains, and standardization is helpful in providing rules and frameworks to support companies move towards the CE.

This study addresses the barriers to the CE in manufacturing industries and aim at shedding light on how these barriers can be overcome by applying information technology.

In this study, we refer to manufacturing industries as industries using highly equipped machines and digital instruments that are helpful in their production. Examples of such industries are construction industry, automotive industry, defence and arms, energy industry (electrical & petroleum), computer industry and aerospace industry. These industries work with tools such as massive machineries, heavy metals, digital and complex mechanical instruments, drills and cranes and other heavy transport equipment and appliances (GS1 2018). It is crucial for these industries to have a secure method to recycle or dispose of metal and electronics waste that can have hazardous effects on our environment. However, there have been challenges in recycling and disposing of these types of machinery and metals as elements and products that cannot be extracted easily.

Manufacturing Industries

The last couple of decades, we have seen an evolution from a traditional supply chain towards a green supply chain. Environmental-friendly production and consumption activities, reducing the negative effect on the environment, represents a major goal of green supply chains. The focus is not just on the reduction of negative consequences of production processes and residuals, but also on the repeated use of materials through such systems, where transformation is made through a relationship between ecological system and economic growth (Genovesea et al., 2017). In addition, the unique product identification is creating interesting opportunities for transparency in companies' supply chains (Karkkainen & Holmstrom, 2002).

Circular Economy (CE)

Adoption of CE concepts have been the focus of the food industry for several decades. Irani and Sharif (2018) explored the role of sustainable food security with the closed loop business models. CE can be seen as consisting of two parts, where the first part focuses on reducing the impact on the environment, and the second part focuses on creating business models that implement the first part (Torstensson, 2016). Regarding the first part, which concerns reducing the impact on the environment, the Ellen MacArthur Foundation (2015) has given a model of circularity showing which activity-cycles that gives the highest positive environmental impact. The cycles focus on a material's next use. The best next use i.e. most environmental-friendly, would be to close a cycle instead of going to a cycle with lower CE effect or end up in the waste-chain.

Figure 1 illustrates the CE cycles Maintaining, Reusing, Remanufacturing and Recycling (M+3R) and the waste-chain. Maintaining has highest CE-impact, followed by Reusing, Remanufacturing and Recycling respectively, and the waste-chain having the lowest CE-impact (Ellen MacArthur Foundation, 2015; Torstensson, 2016). The waist-chain consists of Waste collectors, Energy-from-waste operators, and Landfill operators.

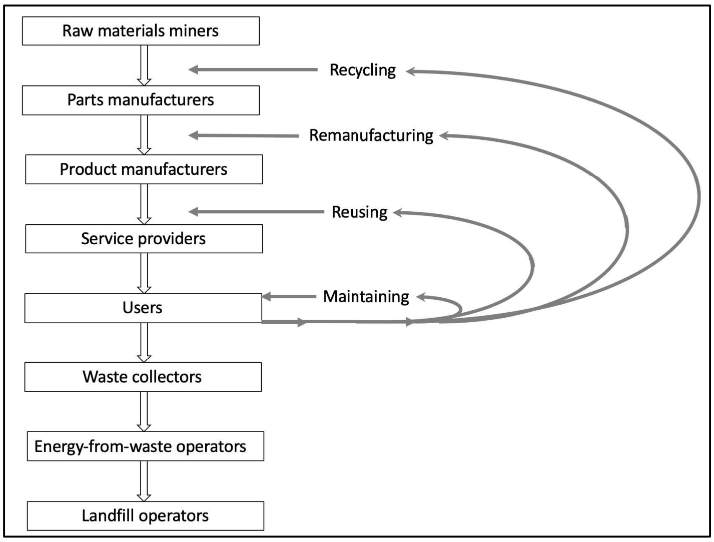

Figure 1 CE as a restorative system for technical products with the M+3R cycles in the upper part and the waste-chain in the lower part (adapted from (Ellen MacArthur Foundation, 2015)

According to Zhijun & Nailing (2007), shifting towards a CE model requires a deep focus on raw materials and energy. When producing a product, the focus should be on minimizing the entire product life cycles negative effects on the environment from the very early stage of material extraction towards the product disposal.

Barriers to CE

A shift to the CE model requires a dramatic change for the whole company involving all stakeholders. This shift is somewhat disruptive in nature because the current mode of working would be changed (Ritzéna & Sandström, 2017). In order to identify common barriers to CE, an exploratory review of existing literature was done using academic databases such as Google Scholar, ProQuest, ScienceDirect and Academia. Keywords such as "Circular Economy, Product Identification, Sustainability, and Barriers to Circular Economy" were used. In summary, the barriers found by (P) Preston, 2012; (LB) Liu & Bai, 2014; (E) Eijk, 2015; (T) Torstensson, 2016; and (BB) Berchicci and Bodewes, 2005) are, ordered by the authors: (P1): Resource-Intensive development models. Traditional models are highly resource intensive; less resource-intensive models are lacking. (P2): High start-up costs. In the long run the CE model would show sustainable benefits and increase growth but in the short run, the start-up costs are high. (P3): Supply chain complexities. Multiple companies around the world are engaged to make a particular product for a global customer base. A challenge for the supply chain in the CE model is the alignment from the early design stage to consumption the durability and reparability of materials. (P4): Difficulty in coordinating companies. The coordination among companies is a barrier because it needs multiple companies to adjust their daily operations. (P5): Innovation diffusion challenge. It is critical that new breakthroughs rapidly find their way into the mass market, so that transition to the CE can contribute to tackling climate- and water-related goals in the necessary timeframe. (LB1): Structural. Innovation and flexibility are restricted by organizations` hierarchical patterns. Lack of budget towards the CE model innovation. CE`s strategies are affected by the managers' employment term restrictions. (LB2): Contextual. Competition in the market place restricts the movement towards CE. (LB3): Cultural. Managers are risk averse. (E1): Restricted supply chain. There is lack of enablers to improve cross cycle and cross- sector performance. Lack of exact knowledge of the composition and origin of materials used. (E2): Lack of industrial symbiosis. Industrial symbiosis is based on having good knowledge of material/energy flow within an industrial sector and geographical area. Thus, it requires exchange of information regarding inputs and output to optimize the processes, but this industrial symbiosis is a barrier towards CE because it's costly or difficult to obtain. (E3): Logistics. Information exchange systems in logistics are limited. Cargo flows are handled by logistics, which also includes the reverse logistics and supply chain management. For the CE transition, existing network design is a barrier. The design should support switching between transportation modes. (E4): Product design and production. Removing of toxic material and separation of biological from technical substance is lacking. Shortage of information regarding green suppliers. Current product design is given less attention towards the end phase of products. (E5): Recovery. The products are becoming more complex; the recovery of such products is a big challenge. (E6): Recycling. Recycled materials are sometimes more expensive than the new raw materials. Investing in recycling is seen to be risky on a larger scale. (R1): Lack of technical skills. A barrier is the lack of skills in small and medium-size enterprises. They don't realize the benefit of implementing more advanced technologies that reduce the negative impacts on the environment and would give them costs savings. (T1): Quality compromise. Companies' reluctant attitude towards CE is their concern regarding the quality of materials. They fear materials would be chosen based on the environmental aspects instead of quality of performance. (T2): Disassembly of products is time consuming and expensive. A product is made of many different components which are attached in a way that their disassembly is hard and time consuming and it seems much better to produce a new product than to recirculate the materials, and also it would be very expensive to mould the components in a way they could be available to use again. (T3): No sure recycling, remanufacturing and reusing would help the environment and save money. There is no surety to the companies that this process of CE would definitely save money or protect scarce resources, and it might be the case that producing a new product is less costly than reusing the old one. (T4): Quality assurance. A barrier is that it is difficult to know what has exactly been done with the material and whether the recycled material is handled in a manner that is good with respect to quality, and all these things involve costs. (BB1): Design irrespective of CE. The products that are produced lack a circular design which is the reason the reusing, disassembly, remanufacturing etc. is hard. (BB2): Hygienic issues. Some perceive that recycled or reused materials are not safe and hygienic.

Data Collection
In order to explore how manufacturing companies look upon the CE concept, and what barriers they see, we carried out semi structured interviews with three companies. since semi-structured interviews are one of the most used methods of data collection within the social sciences (Bradford & Cullin, 2012). The interviews were conducted in three companies A, B and C, working with technical issues and who focus on the idea of green supply chain and sustainability. In the interviews, we aimed at gaining information about their internal capacities, challenges and barrier that they encounter each day by handling their products. Two interviews were carried out face-to-face, while one of the interviews was carried through by sending the interview guide via email since the person available for a face-to-face interview. Company A is a technology-based company that delivers competitive solutions to meet the power needs of its customers. The company works within the marine and automotive industry, and deliver products and services encompassing power systems, nuclear and many more. The company aims at having a reputable rule to minimize the risk of climate change, low carbon global economy, reduction of environmental impacts from production as well as improving the environmental performance of its products. Furthermore, the company are strongly committed to health, safety and environmental management. The respondent said that they do not exactly use the term CE, but we have all the focus on environmental protection:

> ‘*We have the program called "Revert" which is about minimizing the demand for the new materials in which the metals are being recycled. This also helps in lowering the cost and reusing of finite resources i.e. rhenium, hafnium, nickel and titanium."*

Regarding the question about CE, the respondent said that almost 95% of the engine parts and equipment are recycled and have high quality but the main barrier is the cost of recycling. Through the "Revert" program tons of carbon dioxide are saved compared to using new materials. In addition to the cost of recycling, another barrier the respondent mentioned was the disassembly of the products.

Company B manufactures professional lighting solutions for global markets. Their goal towards a sustainable environment is:

> ‘*Through obligations to comply with local, global government requirements and self-imposed requirements, we will contribute to a lower environmental impact. This implies objectives to reduce waste; increase reuse and; as far as possible, use environmentally efficient transport solutions; reduced energy consumption prevent emission''*

The company complies the law that applies to follow the local and global standards and environmental policies, which is reflected in one of the answers of a former employee:

> *'The company's products also satisfy the WEEE Directives (Waste Electrical and Electronic Equipment), has ISO 14001 environmental certification and policy for Corporate Social Responsibility (CSR) to support a precautionary approach to environmental challenges, undertake an initiative to promote greater environmental responsibility and support the development of environmentally friendly technologies.'*

Company C is Global Standards 1 (GS1 2018) who is a not-for-profit company that develops global standards for business to business communication. GS1 was established in February 2005, by the merger of EAN International (European Article Numbering) and

UCC (Uniform Code Council). GS1 is a leading global organisation dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally. The best known GS1 standards are the barcode and RFID standards. The identification of components and equipment enables efficient processes manufacturing industries. The procurement, storage, assembly, maintenance, repair and disposal of products and their components can be optimised based on GS1 identification standards. GS1 Norway has fifteen employees. This interview was conducted in the Department of Delivery Standards where we interviewed Terje Menkerud, a senior advisor at GS1. GS1 Norway has more than 6300 registered companies in Norway. In response to the question about challenges to the company with respect to sustainability the respondent said:

> '*GS1 is not a logistics company, it came from the retail sector and not many companies see us as a logistics company. This is the biggest challenge to get the actors and the players in the field of logistics to know who we are and get aware our system and get to know how we could we help them in daily business by reducing the cost and solution towards environmentally friendly transportation.*'

He further explained that since a lot of players in the market have their own systems, they don't interact effectively. If you receive some material from another market you have to re-label it. To get the entire community into the same global standardized way of trace and track with unique identification is a big challenge in a way of sustainability. The reason is that if there are globally standardised system all the information about a particular product would be shared which is not the case in most of the countries. Further details of the questions and answers can be found in Naz and Rahim (2019).

Barriers identified to the CE in technical industries

Based on our findings, it seems that Norwegian companies in technical industries know the concept of "circular economy" and that they have a with a high focus on environmental sustainability. Even if they do not use exactly the word "Circular Economy", all their efforts towards environmental protection have the base in this concept. The results indicate that large Norwegian technical companies have special attention towards regeneration of resources, and they have special programs to implement such thought as illustrated by the "Revert project", the "sunshine program" etc. mentioned by the respondents. Company B's move towards a sustainable environment is pushed added by charging their customers a small recycling fee that is transferred to the recycling funds to handle recycling. Company B has a membership in an association of recycling companies that make sure the electronic product waste is handled carefully and that products are reused instead of new raw materials. By doing this energy consumption is saved, and environmentally friendly products are produced by reducing the global waste. The company is also certified with ISO 14001:2004. This makes the company to comply with the rules and regulations of the environmental management system thereby reducing the negative effects on the environment. There are several barriers to CE adoption as identified by the literature review part.

The companies interviewed identified the six barriers: coordination problem, quality issue, disassembly of products, design and production, supply chain complexities and high start-up costs.

In end-of-life management, the disassembly of products is considered to be an important element. It is considered that almost every product has some amount of disassembly i.e. irreversible joints, maintenance and up gradation and degradation during use. It is not actually the reverse process of assembly. If the instructions of disassembling are available with other relevant information such as design and life cycle information, it will ultimately help in product disassembly automation and decrease in disposal or components (Parlikad et al., 2003). All the respondents said that the disassembly of products is not easy and it expensive and time consuming because of complex nature of products and this fact is also supported by the literature (Torstensson, 2016). The complexity comes due to different aspects. The number of materials has increased, and many small materials are used with significant importance as well as the multiple components of different nature and connections assemble together and affect the transition towards a CE. If the resources contained in these materials and components are taken back through repair, upgrade or remanufacture can benefit the overall world (Peiró et al., 2017).

Another barrier which the companies have mentioned the technology sector is less attention towards the end-phase of product (Eijk, 2015)**.** One of the problems is the production of cheaper goods, shorter-life expectancy and low cost and unsustainable products in today's corporate culture. The culture of companies is, when they make a product, they don't feel the need about how the product will end its life. Once the manufacturers produce the product and send it off for sale, they are not usually responsible for the end-phase of the products' life. Furthermore, they report lack of information when recycling or reusing any product in their end phase of life, because product information is necessary to identify and know about the product parts. This has concerned governments and organizations to make strategies to pressurize companies and the corporate world to be more responsible while producing and have strict environmental considerations & policies (Hesselbach et al., 2001).

Recommended model to overcome CE barriers

We provide recommendations to the companies in technical industries for overcoming the CE-barriers based on an information model built on top of international product information standards by global Standards 1. The GS1 Standards being used by the retail sector for decades are currently being developed to fit the manufacturing industries. GS1 provides standards for identifying, capturing and sharing information about unique products, parts, components and assets, business locations, and documents that enable industries to achieve visibility and life cycle management including the maintenance and repair processes (GS1a 2019).

By uniquely identifying products and components companies can use the identifiers to look up information about the product in a database provided by the manufacturer. E.g. during the end-phase of product life dis-assembly can be eased by scanning the product identifier to use it for lookup of dis-assembly information provided by the manufacturer. The unique identifiers, therefore, needs to be attached in the initial design and engineering stage of components and products. To illustrate this, we use a crane as example. In the model, the crane has different components namely, trolley, hook, sewing bearing, cab, wedges and counter weight. Each component is given a different Serialized Global Trade Item Number (SGTIN) to be attached to the component. The unique identifier can be encoded in e.g. a UPC barcode or an RFID tag. When these components are assembled, the final product "crane" gets another unique SGTIN identifier linking the crane SGTIN to each SGTIN of its components. The SGTIN attached to each of components would help in the later stages of disassembly such as maintenance, reuse, remanufacturing and reuse. The SGTIN information related to a unique crane is stored in the company data base. SGTIN will have information about manufacturing companies, the suppliers and material used e.g. master data and information about bill of materials. The sharing of information is under the control of the manufacturer due to the security issue and threat from competitors. When the authors asked respondents, they argued that threat of copying of our components and material used inside the component is a big challenge they cannot share it publicly. In our model, we propose that the master data of company to be saved in the GS1 data base i.e. GS1 cloud and GDSN (Global data synchronization network). GDSN allows GS1 to be connected to different companies that want to exchange product data with their supplier or recycling companies. The information sharing of GS1 include data standards for master data, business transaction data, and physical event data, as well as communication standards for sharing this data between applications and trading partners (GS1 2018). Master data are valuable information about products of any company, it is stored in GDSN. In order to obtain information, the companies should register in the global register data pool by GS1.The GDSN can automatically share the business data with their trading partners (GS1 2018). This means that the required information regarding the product or its components will be shared and updated between the actors, i.e. the technical company and recycling company. In particular, to the company and GS1, GDSN will be a connecting network that will help the company to share and exchange their data in order to recycle and reuse its products and attain sustainability. For the sustainability of products, companies need to identify, measure, compare and transform the factors that improve production and consumption. Many of these factors inhabit the supply chain, as it is common having problems in complexity and problem in disassembling the parts. Using GS1 standards will help systematize supply chain data, ease its exchange and make efficient reporting against a sustainability profile (GS1 2018). In the GS1 Cloud, the data maintained in the GDSN database about brand-sourced data and the member organizations product catalogues are combined together with six new features about GTIN, Brand, label description, target market, product classification, company name. The data about crane components will be shared with the GS1, GDSN and GS1 cloud with permission from the producer and the information would only be given to the recycling companies i.e. Norsk Gjenvinning and Romerike Avfallsforedling IKS, by allowing access only by using the passwords and encryption of data. The recycling companies if get all the necessary data related to components and their material content. It would help companies in disassembling of components and recycle efficiently. For the privacy of information of manufacturing companies and their confidential data about product components there can be passwords, encryption that would be allowed to its users only. In a complete CE transition waste should be designing out always providing a next-use of materials. Products such as machines, electric equipment and other products with harmful substances, the substances should be extracted and reused. Hence, GS1 standards can help companies in extracting the harmful substances by giving company a specific identifier to each of their product and components. The *lack of product information about product design and production* is a barrier and this barrier can be removed by providing more accurate information. For this purpose, product information must be exchanged with product designers for later use in recycling, reusing and repairing. Consequently, another strategy to overcome this barrier can be, by formulating regulations for manufacturing industries to make them obliged to share product design information to the concerned recycling companies. The GS1 Global Data Synchronization Network (GDSN) concept can help in advancing the overall quality of the product information by automating exchange of master data information with trading partners. The GDSN concept has already been successfully deployed in health care by implementing unique device identification (UDI) in pharmaceutical companies. This implementation has increased the efficiency and flexibility, while also supporting regulatory requirements (GS1, 2018). We propose a model for the technical industries based on the same principles applied in the health sector. See Figure 6.3 for the general concept. For details see (Naz and Rahim 2019).

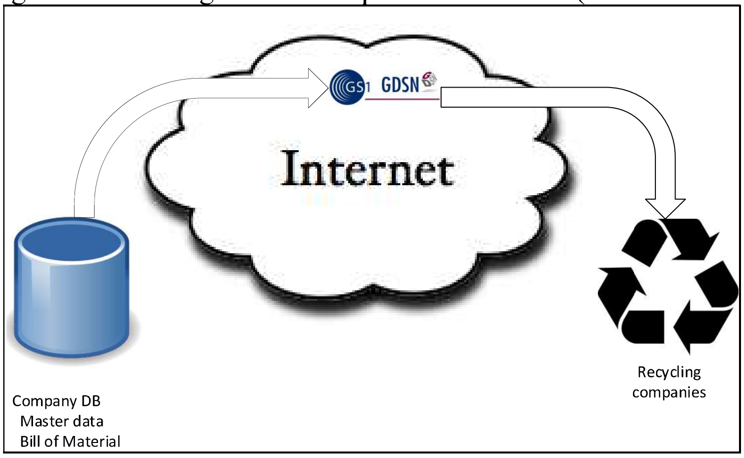

Figure 6. 3: Recommended Model for shift towards circular economy

Supply chain complexity and co-ordination problems depends on the information system used and differs from company to company. GS1 provide the standard EPCIS (Electronic Product Code Information Systems) for information systems that handle trace and track of products across their life cycle and across companies. Following the standard, companies can have a shared view of information related to each other's businesses. This would *reduce supply chain complexity, give more visibility and support coordination*. In addition, sharing of information about products and components with following GS1 standards would help recycling companies to disassembly products for reuse and recycling. Hence, through identification standard with EPCIS code, sharing would be possible with all the recycling companies and other relevant partners to overcome the barriers of complexity and cooperation in supply chain, disassembly of products by the recycler and product design and production by the engineers and producers.

Conclusion

In this paper we have identified barriers to the CE transition of manufacturing companies by doing a literature review. By carrying out case studies of three Norwegian companies, we found that the major barriers for implementation of CE were a quality issue in recycled materials, supply chain complexities, coordination problem between companies, design and production of the product, disassembly of products and high start-up cost. These barriers are a sub-set of what we found in the literature on barriers. Our findings show that the companies are well aware of the challenges of moving towards the CE. To help companies to overcome the barriers we proposed a model for a product information management system to be used by companies.

Limitations

The main limitation is the limited amount of data collected due to companies' confidentiality concern. Another limitation is that this study only focuses on one standard "identification" due to time constraint. Companies in this research have answered about CE and barriers in implementation but they, in reality, have only started on the CE adoption. Our proposed model should be tested to assess its applicability, and the use of GS1 standards should be contrasted with other standards.

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