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Resource recovery from post-consumer waste: important lessons for the upcoming circular economy

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ABSTRACT

A circular economy has been proposed as a sustainable alternative to our current linear economic system, mainly by recirculating material resources for new product development. To understand resource recirculation in practice, this paper analyses over 50 examples of products developed from discarded materials, categorising them into the recovery routes described in the circular economy literature. The examples were obtained during interviews with waste management professionals and designers who had developed products with discards. Practical challenges to implementing a circular economy were identified based on the example categorisation and comments from the interviews. The main difference observed was that the examples mostly recirculate resources to make different types of products, whereas a circular economy requires manufacturing companies to take back their own products to secure their material resources. This is partly because in practice the material collection system in place is waste management, rather than manufacturing-centred take-back systems. A revised model for recovery routes in society in which waste management is allocated an important role in facilitating material recirculation is therefore presented. The study highlights that current product design is facing a new challenge of anticipating social, economic and environmental challenges to realise the goals of a circular economy.

1. Introduction

Several actors have identified potential business opportunities in aiming to achieve more circular material loops in manufacturing and production and describe how possible recovery routes could be defined (cf. Ellen Macarthur Foundation, 2014). They also discuss how designers and manufacturers can help move towards a more circular production model. This paper compares such literature about the circular economy with its potential practice. It does so by presenting examples of 'circular' products, using data obtained from an interview study, and categorising them using the resource recovery routes described for the circular economy. This categorisation was intended to highlights aspects of the circular economy that the theory has not yet addressed. The interview study generated a list of over 50 examples of products that help recirculate materials, while also providing information about the challenges material recirculation has today. This information and the issues raised when categorising the examples were used to examine how well aligned the theory and practice of circular economy are and to identify possible practical challenges not accounted for in the literature.

The article is outlined according to the following: Section 2 provides a brief overview of the resource recovery routes in the literature on waste management hierarchy and circular economy; Section 3 presents the methodology employed in this article to study the product examples; Section 4 presents the important results from the product study and interviews; and finally Section 5 ends the paper with discussion and conclusions.

2. A brief overview of resource recovery routes

Since 1975, when the European Union first introduced its waste hierarchy, it has been adopted by many countries to establish long-term policies to guide the waste sector (Williams, 2015). The waste hierarchy has been described as a "ladder" to be climbed step-by-

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Table 1
Some examples of reuse for different products.

Products	Some facts about material flow patterns			Comments
	New stock	Reuse/Resale	Wastes/Recycle	
Cars in EU (BCA, 2013)	2 million cars	7.1 million cars	**No data**	
Mobile phones in USA (Geyer and Blass, 2010)	**No data**	65% of the phones collected were reused	35% of the phones collected were recycled (Geyer and Blass, 2010)	Only 20% of the total discarded mobile phone were collected, the rest were mostly kept by owners or handed over directly to second-hand users.
Clothing in Sweden (Carlsson et al., 2011)	15 kg/capita & year	3 kg/capita & year sorted out for charity	8 kg/capita & year were discarded into waste streams in the same year.	The outflow of clothing is very rapid and there is huge potential to reuse or recycle the clothing if collected separately.
		In 2008, of the total sorted clothes collected by Myrorna (a second-hand store in Sweden), only 20% were re-sold in Sweden (Myrorna, 2014)	80% was exported for reuse and recycling	

step from bottom (landfill) to top (waste prevention) (Williams, 2015). Since the inception of the waste hierarchy, several amendments have been made to address the issue of waste, the latest being in 2008 (Waste Framework Directives; (EU, 2008)). *The new waste hierarchy contains measures for prevention, preparing for re-use, re-cycling, other recovery and disposal.* However, recent studies (Gharfalkar et al., 2015; Van Ewijk and Stegemann, 2014) have pointed out limitations of the waste hierarchy. These include a lack of guidance on selecting among the levels in the hierarchy, overlaps between various measures within the hierarchy and limited support for decisions that affect other sectors. These studies propose a refined hierarchy of resource use and adoption of value-based conceptions of waste and related collection practices. For example, Gharfalkar et al. (2015) propose an hierarchy of resource use based on the inputs from DG Environment of the European Commission, DEFRA (Department for Environment, Food & Rural Affairs) and WRAP (Waste & Resources Action Programme).

In the current predominantly linear production and consumption systems, resource recovery is considered to be one of the important aspects of waste management (WM) (El-Haggar, 2007; Eriksson et al., 2005; Griffiths et al., 2010; Lavee, 2007; UN Habitat, 2010). Globally, only 30% of the total waste material collected involves resource recovery (material recovery 11% and energy recovery 19%) (Chalmin and Gaillochet, 2009). These WM statistics provide an aggregated view of the established resource recovery operations linked to the total amount of collected waste. For some waste fractions, relatively more information is available on the total material consumption, material stocks and end-of-life waste material handling. For example, the European demand for plastics during 2013 was 46.3 million tons, of which more than 40% was added to the European "plastics stock" in that year, discarding only 25 million tons (~54% of the demand). For the discarded plastics, the share of material recovery, incineration and landfill was 26%, 36% and 38%, respectively (PlasticsEurope, 2014).

Furthermore, the amount of materials/products diverted for reuse (repair, refurbishment and remanufacturing) is also largely unknown, except for some specific second-hand markets for high value products and/or reuse enabled by intermediaries (such as local government, waste institutions, second-hand shops or websites). Table 1 presents some examples of reuse of post-consumer products in different regions. These examples indicate that a large percentage of post-consumer goods are stocked in the use phase. Indeed, for many products, there is no data availability on their stocks and therefore their reuse/recycling potential is largely unknown. The data shown in Table 1 are available because the intermediaries organising the reuse/resale are required to keep such inventories for their internal records. Moreover, the remanufacturing potential for many products is unknown. Remanufacturing is not well-established in practice except for some high value products with low technological/fashion/trends changes such as earthmoving machinery (All-Party Parliamentary Sustainable Resource Group, 2014).

Lately, the 'buzz word' circular economy (CE) has been popularised, especially in the industrial economies,[1] by the Ellen Macarthur Foundation (2012). CE is an economic strategy that suggests innovative ways to transform the current predominantly linear system of consumption into a circular one, while achieving economic sustainability with much needed material savings (Stahel, 2013). The principles presented by CE are rooted in different schools of thought, such as industrial ecology, biomimicry and cradle-to-cradle (McDonough and Braungart, 2008; Mentink, 2014; Yuan et al., 2006). CE proposes complicated system operations (such as product-service systems, remanufacturing and repair) for an industrial economy that are restorative and rely on renewable energy (Ellen Macarthur Foundation, 2014). This is achieved by designing and optimising products to eliminate waste by enabling efficient reuse, disassembly and refurbishment. CE advocates separate collection and utilisation of recovered materials (from consumables and durable products) within the same product chain. This would help achieve maximum efficiencies (material, economic and environmental) by collectively managing and sharing the activities among actors within the product value chain. Within CE, industrial systems mainly rely on maintenance, reuse/redistribute, refurbish/remanufacturing and recycling, while minimising resource leakage through energy recovery and landfill. Various sources of value creation in a circular business model employ these operations (All-Party Parliamentary Sustainable Resource Group, 2014).

That source distinguishes various processes within the circular economy — repairing (fixing fault but with no guarantee), reusing (simple reuse without any modifications), refurbishing (aesthetic improvement with limited functionality improvements), reconditioning (potential adjustments to the item to bring it back to working order), recycling (extraction of raw material for use in new products) and remanufacturing (series of manufacturing steps acting on end-of-life part of product to produce as-new, better performing products with warranty).

The difference between the resource recovery routes within CE and in the waste hierarchy lies mostly in the way discarded products/materials are perceived. CE aims at phasing out waste from

[1] Except for China, where CE has been incorporated into national policy for sustainable development since 2002 (Geng et al., 2012).