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Towards facilitating circular product life-cycle information flow via remanufacturing

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Abstract

In order to achieve a sustainable development, circular economy approaches and circular material flows are explored in industry. However, circular information flows remain essentially unestablished. The aim of this paper is to: 1) explore categories and types of product life-cycle information available for remanufacturing; 2) identify constraints for efficient product life-cycle information flow via remanufacturing; and 3) propose initiatives to facilitate product life-cycle information flow via remanufacturing.
Data was collected through workshops and interviews at five remanufacturing companies. An accumulated Sankey diagram illustrates product life-cycle information flow, losses and bottleneck. Based on the analysis, possible initiatives to facilitate efficient product life-cycle information flow via remanufacturing are presented.

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Keywords: Remanufacturing; Product life-cycle stackeholder; Feedback; Feed forward; Sankey diagram

1. Introduction

While achieving sustainable development via circular economy, resource efficient production system and closed-loop supply chain are challenged [1-6]. In order to develop circular economy, circular material flows have been explored [7-10]. However, circular information flows remain essentially unestablished [7 and 11].

Circular product life-cycle (CPLC) information originates from various CPLC stakeholders in the product life-cycle: *Product Development*, *Manufacturing*, *Use/Service*, and *End-of-life* (see Fig. 1). This information is collected in the form of tacit knowledge, practical experience, customer feedback, paper manuals, software, hardware, pictures and advanced specifications [11, 12].

Major CPLC stakeholders often fail to share available product data with the stakeholders in the end-of-life phase, e.g. between Original Equipment Manufacturers (OEMs) and competing independent remanufacturers. As a matter of fact, remanufacturers insist on product life-cycle information sharing across the product life-cycle stakeholders [12].

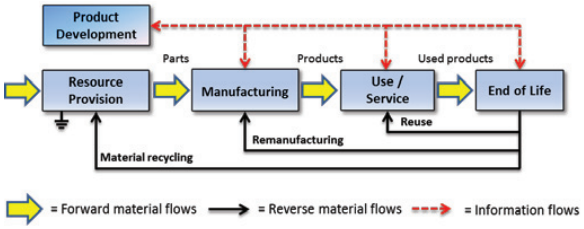

Fig. 1: Product life-cycle (adopted from [11]).

Ideally efficient CPLC information flow would benefit all product life-cycle stakeholders. The main benefit of product information is greater customer satisfaction through improved product performance and level of service. The increase in product knowledge at each CPLC stakeholder would contribute towards a more efficient circular economy. Consequently, a circular economy would stimulate product circulation and multiple product use, implying transparent and accessible product life-cycle information flow across a system of shared values [13].

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1.1. Aim

The aim of this paper is to:

1. explore categories and types of product life-cycle information owned or received by remanufacturing;
2. identify constraints for efficient product life-cycle information flow via remanufacturing; and
3. propose initiatives to facilitate product life-cycle information flow via remanufacturing.

1.2. Research approach and data collection methods

In order to fulfill the aims of this paper Material and Information Flow Analysis (MiniMifa) workshops and semistructured interviews were performed at five remanufacturing companies [11, 12, 14]. In three of the companies, the interviewees worked in the product development, manufacturing, service and remanufacturing departments (see Table 1). In parallel, MiniMifa workshops were performed at three of the companies. The objective of the interviews and workshops was to identify the product life-cycle information owned or received by remanufacturers. The focus was to identify the remanufacturers' contribution to information generation, which could be provided as feedback to the other CPLC stakeholders.

Table 1. Case company characteristics and data collection methods.

Characteristics	Case A	Case B	Case C	Case D	Case E
Company size	Large	Large	Large	Large	Small
Sector	Machines	Machines	Furniture	Automotive	IT
Product complexity	Medium	High	Low	High	High
Remanufacturing experience	10 years	10 years	20 years	20 years	10 years
Remanufacturing business compared to manufacturing	Medium	Minor	Minor	Medium	Major
Remanufacturing status	Contracted	OEM	OEM	Contracted	Independant
Data collection method	Interviews	Interviews and MiniMifa workshop	Interviews	MiniMifa workshop	MiniMifa workshop

2. Circular product life-cycle information

In this section the circular product life-cycle information, identified from the stakeholders at the case companies, is explored and categorized (see Table 2).

2.1 Product Development

During product development the product's properties are determined. Customer data is essential to product designers [15]. However, preferably the product should be designed considering all product life-cycle phases, including manufacturing, use/service and end-of-life [16]. Efficient remanufacturing requires a product design that facilitates disassembly and upgrading, if needed [17]. However, few products are designed for remanufacturing [18].

2.2 Manufacturing

Product development and manufacturing is often carried out within the same company. Additionally, manufacturing staff are often involved, to varying degrees, in the product development projects. Design for manufacturing ideas can be encouraged as some design issues are hard to predict. Feedback from manufacturing personnel tends to be on concrete and detailed level of the product design features [19].

2.3 Use/service

Service can be maintenance, replacement of parts, upgrading and instructions on how to best use the product in order to prolong the use phase [20]. Service also means interacting with the users, enabling information feedback [21]. Design for service should be carried out in order to more easily obtain increased revenue and environmental benefits [20]. In order to facilitate forecasting of when a product is in need of service, modern ways of monitoring products from a distance could be efficient. Thus, condition monitoring is one way of capturing product use data and feeding it back to product development [22].

2.4 End-of-life via remanufacturing

Remanufacturing is one of the most effective ways of managing a product's end-of-life [23, 24]. According to several comparative studies on environmental research, remanufacturing is more environmentally sound than new manufacturing and material recycling [25]. By bringing used products back to useful life, remanufacturing puts the product life-cycle into a sustainable loop [26]. Remanufacturing is an industrial process and often consists of several steps, e.g. inspection, cleaning, disassembly, testing, reprocessing and reassembly [27]. However, today remanufacturers depend more on established product life-cycle stakeholders, like manufacturing [26]. Moreover, insufficient information flow within the product life-cycle, multiple networks that interface poorly with one another and miscommunication all hinder closing the product life-cycle loop via remanufacturing [24, 26, 28].

There are three different kinds of remanufacturers, OEMs that remanufacture, contracted remanufacturers and independent remanufacturers [21]. OEMs that remanufacture are in control of the both product development and product recovery, while a contracted remanufacturer receives some information from the OEM and could provide the OEM with feedback, whereas an independent remanufacturer is a competitor and often treated as such [29].

3. Analysis of the product life-cycle information flows

3.1 Categories and types of product life-cycle information

The analysis of product life-cycle information flow derives from the data collected at case companies and presented in Table 2. The categories and types of product life-cycle information are classified in the first two columns. Additionally, the level of product life-cycle information accessibility, format, description, stakeholders' status as O