Reverse Logistics for Improved Circularity in Mass Customization Supply Chains

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Abstract. Manufacturing companies that seek to improve circularity performance across the supply chain, face many challenges in the transition of traditional linear approaches into more circular supply chain models. Reverse logistics is a key area for reuse, recycling and refurbishment of products and materials, where collection and material handling are often critical barriers. This research identifies strategic aspects of reverse logistics in circular supply chains, with focus on mass customization. A literature review on reverse logistics and reverse supply chain management is carried out and used as a basis for a case study of a mass customization furniture manufacturer. Key aspects of a reverse logistics strategy in mass customization settings are discussed, considering supply chain, product and customer-related factors. The large variety of products often complicates collection, material handling and recovery processes after end-of-life. This study presents further insights to strategic reverse logistics aspects for improved circularity performance of mass customization manufacturers, for instance how modular product architectures across the product portfolio may be beneficial for increasing circularity.

Keywords: Reverse logistics · Supply chain management · Closed-loop supply chains · Furniture manufacturing · Circularity strategies

1 Introduction

Reverse logistics (RL) is a vital part of a circular economy and has the potential to decrease material usage of manufacturers by enabling reuse, recycling of refurbishment of products [1]. Making a transition to a circular economy requires a fundamental change, influencing design, production, distribution, consumption. RL can be defined as the process of planning, implementing and controlling backward flows of raw materials, in-process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or proper disposal [2, 3]. Due to a combination of economic, environmental, and social factors, reverse logistics is becoming a key competence in modern supply chains [4, 5].

From start-ups to big brands, businesses are offering more personalized product options to extend their product lines. Mass customization (MC) as a business strategy

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profit on the fact that customers have individualized needs, and their solution space will continue to develop due to the customers changing needs [6]. The products often consist of modules with common interfaces making the solution space immense in terms of number of variants. MC companies thrive to deliver according to the customers' expectations while keeping a mass production efficiency [7]. It has enabled many companies to penetrate new markets by capturing customers whose personal needs were not met by standard products and services. This implies a large variety within the product portfolio which complicates the establishment of efficient reverse logistics systems for further handling of end-of-life products.

The purpose of this paper is to identify key strategic aspects of reverse logistics and present challenges and opportunities in achieving reuse of materials in MC products compared to mass production settings. The aim is to gain greater insight on how MC both enables and inhibits the transition of traditional linear approaches into circular supply chains, with focus on reverse logistics. The remainder of the paper is structured as follows. First, a literature review is presented, followed by a description of the research approach applied, including an introduction to the case company. Thereafter, the empirical data is presented, followed by a discussion of findings. In the conclusion, main findings are highlighted and directions for further research are proposed.

2 Literature Review

The transition to a circular economy may have major consequences for MC companies. While current research is mainly concentrated on specific areas within reverse logistics and closed-loop supply chains [8, 9], and only few studies address issues specifically related to MC products. Thus, literature addressing MC issues related to RL is still scarce.

To increase the level of circularity, mass customizers can adopt a range of end-of-life (EOL) strategies for their products, including refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover [10]. Reverse logistics plays a vital role for succeeding with these EOL strategies. RL is the process of planning, implementing and controlling backward flows of raw materials, in-process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or proper disposal [2, 3]. In a supply chain perspective, the RL process mainly involves the backward flows, such as collecting and sorting products from end-users and managing these products to be used in new value streams.

In general, product customization is considered a major barrier for increased circularity since custom products are produced to satisfy the individual needs of a specific customer [11, 12]. High product variety and high degree of customization typically requires a high number of potential spare parts, complicates demand planning, and hinders efficient optimization and automation of disassembly processes [13]. Different EOL strategies may have different implications for MC products, depending on aspects such as reconfigurability, customer demand fit, modularity, parts variety, product variety degree and custom components [13]. While the reuse strategy can be especially challenging, due to that MC products are tailored to individual customer needs, MC products that are reconfigurable and can be adapted after purchase may allow for further customization

of products to the needs of new users and thus increase the chance of reuse [11, 13]. For customized products return policies may be more difficult to establish, since these are produced to satisfy the individual needs of a specific customer [11].

Modular product designs and parts commonality, which are typical MC product features, are recognized as an enabler for managing returned products, especially related to remanufacturing and recycling [13]. Modular product platforms supports the use of shared components and modules for product families, and facilitate component replacement, disassembly and re-assembly [13]. Customized products tends to lead to a higher complexity when products are disassembled for remanufacturing [12]. However, due to the modular architecture of MC products, re-designing and remanufacturing are considered as especially applicable EOL strategies [11].

High uncertainty in return flows regarding quantity, mix, quality, time and place reduces the chance of achieving economies of scale in reverse logistics activities [14]. Companies may develop partnerships with actors who have access to intellectual property, know-how and necessary information [12]. A major challenge is to find appropriate supply chain partners and to ensure that partners have specific skills and competences for handling the reverse logistics processes, especially when when handling products with high complexity and customization [12].

The customer is a key actor in a RL system [2]. Without returned products there will be no reverse flows. Successful performance of a RL system depends on customers willingness to return their obsolete products to a complete cycle [15]. The profitability of a reversed network increases when number of returned products increases [16]. Thus, specific measures can further encourage customers to initiate the return flow, such as offering discounts, charity donations or vouchers for bringing back end-of-life products [2, 17]. Also, customers willingness to return EOL products have been found to increase after governmental incentives [17].

To summarize, the reverse logistics systems of a mass customization company is dependent on supply chain factors (e.g. network design, partnerships, and competence), product-related factors (e.g. product variety, inflow volume, and product modularity), and customer-related factors (e.g. relationships, awareness, and incentives). These three domains will be used in the further analysis of the case.

3 Methodology

This research is based on a literature review to identify key aspects for RL strategies for MC companies, combined with empirical case data collected from a large European manufacturer. The literature review aimed to identify strategic aspects of a reverse logistics system. Search engines combined with snowballing method were used to identify relevant literature.

The empirical data were collected from a manufacturing company within the furniture industry. The furniture industry contributes large waste volumes, has low product recovery rates and have a major improvement potential. Today, approximately 10 million tons of furniture are discarded every year in the EU, and the overall recycling rate for furniture is estimated at only 10 percent [18]. The case company was selected due to its match with three criteria: use of mass customization, experience with reverse logistics and sufficient company size (sales and production in multiple markets).

Various methods for data collection were used throughout a two-year period, such as site visits, workshops, observations, and interviews. Respondents were selected based on relevant competence and represented top management, operations and supply chain, research and development, sales and marketing, product, category and branding, country, and commercial, environmental, and business development. Interviews were semi-structured with a set of guiding topics. To add further insight to current practices and potential development for RL system for furniture, four other leading companies were also part of the investigation. The data collection was carried out between 2018 and 2019. In total, primary data sources consisted of 10 interviews, 5 site visits and 3 workshops. The study is part of three-year research project funded by the Norwegian Research Council, addressing circularity strategies for the furniture industry.

4 Case Study Results

The case company is a European manufacturer, headquartered in Norway, that offers customized products within the office furniture industry. MC is enabled through modular product architectures, from which a wide variety of products can be configurated and assembled. The case company has dedicated over forty years to sustainability and design and has become a leading supplier of furniture with low environmental impact.

The supply chain of the company has grown to include international operations with several factories in Europe, the USA and Asia. Their products are sold globally, with an export share of 80%. A main challenge for the case company is to ensure a stable volume of returned products. The case company operates within the business-to-business (B2B) segment of office furniture. Many retailers manage the relation to the end-customer; hence the retailer has a major role within the RL strategy through communicating and providing customers with necessary knowledge.

Due to varying environmental awareness across markets and fluctuating volume of inflow, it is challenging to identify partners and establish a set of roles and responsibilities in the reverse supply chain. In one of their international markets with a high demand of recovered products, the case company has established collaboration with a third-party supplier. The service provider specializes in RL activities and offer recovery services for four product brands of the case company. It is challenging making the reverse supply chain financially feasible due to unpredictable inflow of used products as well as uncertain demand of refurbished products, but they achieve a high level of social and environmental profit. By dismantling and rebuilding products according to certified procedures, components are reused or replaced. The service provider conducts four main decision processes for the reverse logistics process: preliminary sorting based on products brands, transport considerations (recovery centers vs. manufacturing facilities), component quality (level of defects) and separate sorting for recycling.

A main product characteristic for the case company is a modular architecture across the product portfolio. Standard locking mechanisms enhances the disassembly process and facilitate separation of components. Even with a large product variety, the common interfaces enable dedicated disassembly lines to improve efficiency. Modular components, product structure and standard locking mechanisms is part of design for disassembly and helps to improve efficiency across product brands and makes it easier for

RL partners to perform the disassembly. However, the furniture's long lifespan and uncertainty in product inflow makes the financial risk high.

Through monitoring used products in recovery, the case company and their RL partner can identify usual wear and tear and give feedback to internal operations that helps improve product development, manufacturing, and re-manufacturing so they continue to manage to reuse and recover a larger part of the products. When the case company or the RL service provider experience components that often breaks when transporting or dismantling the products they change the manufacturing process to fit the RL activities better. The company is planning to at expanding their product range with smart furniture features with self-monitoring and communication capabilities. This can become a vital tool for aiding partners in sorting and quality control.

Customer requirements in selected markets places high demands for documentation. Circular tenders require proper product data regarding circular performance, such as tracking of materials and emissions within transportation. The product information required includes a wide range of material information from multiple tiers of suppliers and partners in the supply chain. Information and communication technology (ICT) systems that support sharing information on products and suppliers across the supply chain are critical. As information is rapidly outdated and new suppliers enter the supply chain, more efficient data sharing is needed to further improve RL systems.

Through the strategic collaboration with the service provider, they offer a buy-back solution that constitutes an incentive for return in selected markets. Customers contact the service supplier when they need to upgrade their furniture. Customers rarely have furniture only from one brand and supplier, so the service provider must resell furniture they lack competence to recover efficiently. The screening process is a critical aspect of an efficient RL system. It demands a high level of product competence of the service provider to assess the quality of the parts and whether they can recover the components or not. The case company experiences that most customers are seldom aware of how to maintain the products, and a lack of spare parts of older models makes it challenging to repair some products.

5 Discussion

The literature review and the following case study show that MC presents both challenges and opportunities for achieving a circular business model with reverse logistics, and will be discussed considering supply chain, product and customer-related factors.

5.1 Supply Chain Related Factors

A major concern for reverse supply chains is the predictability of products returned from the customer. High uncertainty in volume, quality and product mix of return flows make it harder to plan for different recovery option (re-use, repair, refurbish, re-manufacture or recycle). The network design of the supply chain plays a critical role, as the number of actors involved can confound the return flow substantially. Issues of return policies and responsibilities for used products gets more complex as the number of actors increases. In our case company, the manufacturer is reliant on sales through a high number of

retailers, who are then becoming the contact point for the end customer in case of a product return. The management of partners for collection, sorting and disassembly therefore becomes crucial for succeeding with reverse supply chains.

The competence and skills of the partners are also vital in ensuring that the correct decisions are made when assessing returned products. Detailed product knowledge is vital for assessing residual value of products and proper actions. As identified in our case, the capability of sharing product data and coordinating service and repair-efforts are therefore vital in building efficient reverse logistics activities.

5.2 Product Related Factors

The product variety offered by a company, combined with components variety for each product, is a clear contributor to high product complexity. The high complexity of MC companies could complicate spare parts planning and distribution and be impeding efficient disassembly and re-manufacturing [13]. As learned from the case, the adherence to modular product structures with shared product platforms is a key element for MC companies to overcome the inherit complexity of MC product structures.

The modular product architecture provided the case company to create the desired amount of variety to customers, but it also supported key steps in the reverse logistics process, related to sorting, disassembly, and refurbishment of their furniture. The modular architecture of MC products makes them apt for recovery. In this regard, remanufacturing of an MC product would be more cost-efficient compared to a product with integrated product architecture. For modular products to be easily disassembled, companies can take important steps in the initial product design phase. For customized products, a "reuse" strategy might seem challenging since MC products are tailored to the individual needs of the respective customers. Hence, it seems unlikely that the product and its attributes fit an entirely different consumer and can thus be re-used. From this perspective, an MC product initially seems quite non-reusable. However, it can be argued that if a product contains the possibility to adapt or reconfigure after purchase, the likelihood of re-use increases. Capabilities of reconfigurable products can countermeasure the decreased flexibility of individualized products. With the growth of sensor technologies and smart product features, the ability for soft customization, achieved by software, can contribute to prolonging product life. Further, adding self-monitoring capabilities to products can be vital in initiating return loops (when a component is failing) and assessing the quality of the product needed for efficient sorting and disassembly.

5.3 Customer Related Factors

Individually adapted products are assumed to have a greater use value for the customer, and thus a longer service life. In this sense, the use of customized products can help reduce the "use-and-throw" mentality that mass-produced goods can promote. From a circularity standpoint, MC is contributing to extending the product life span. As each product is manufactured or assembled only after a customer order is obtained, it reduces the stock of finished goods and risk of obsolescent products. Governmental incentives and requirements can support increased circularity [17], but can also propose challenges for MC companies. As we saw in our case example, there were very high requirements

for documentation in public tenders in certain markets that involved a share of circular products in the procurement deal. Fulfilling these requirements proved tedious and challenging. Improved ICT systems for sharing product information were seen as a measure to counteract this labor-intensive process.

As we have seen in this paper, MC companies needs to overcome challenges related to product structure, supply network design and customer relationships to fulfil this vision and increase the reverse flows of customized products.

6 Conclusion

The main contribution of this paper is to show how MC models offers specific challenges and opportunities related to reverse logistics, including supply chain, product, and customer factors. It provides a contemporary case, that both confirms previous findings, i.e. the role of product modularity in mass customization companies, and its importance for circular economy models, but also extends understanding of customer- and supply chain-related factors.

The supply chain actors are vital for establishing efficient reverse logistics, and relies heavily on network design, information sharing, partner skills and competencies. The customer is the key initiator of reverse product flows. The customer role can be strengthened by accessible knowledge, close customer relationships and clear return policies.

Higher product complexity from high parts variation, custom components and individualized design can complicate reverse logistics flows related to key EOL strategies, such as repair (access to spare parts), reuse (customization) and re-manufacturing (disassembly efficiency). However, the modularization strategy of MC with shared product platforms and interfaces can facilitate both reverse logistics flows and recovery processes. Making reconfigurable products with smart self-monitoring capabilities can further aid efficient product return flows and product recovery. Guidelines for design for disassembly and design for reuse serves as the basis for achieving efficient reverse logistics for circular business models.

Further research is called for to study how MC can further contribute to expanding the life span of products. Current MC principles and frameworks need to be further adjusted to circular business models for the customization option also being the sustainable option.

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