The Most Critical Decisions in Manufacturing: Implications for a Circular Economy

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Abstract. Through product development and design, manufacturers wield great influence on the entire product's life cycle resulting in creating value to customers and thus, have great potential to decouple this value provision from linear resource consumption to a Circular Economy (CE). However, since CE is a systemic concept rooted in the principle of conservation of resources, its implementation cannot only be done in one of the firm's functions or facilities, as it requires collaboration and commitment enterprise wide and conscious management of stakeholders. In view of this, the current research focuses on the identification and evaluation of the most critical decisions across functional areas in manufacturing and how they may impact the implementation of CE. In so doing, this study contributes with building a solid base of empirical research on CE in the manufacturing sector, hence contributing to literature on CE and manufacturing.

Keywords: Critical decisions, Manufacturing, Circular Economy.

1 Introduction

The progress of manufacturing sector is tantamount to the economic sustainability of a country, which requires continuous upgradation to achieve excellence. Indeed, manufacturing firms are bestowed with resources and capabilities [1] and thus, have a great potential to drive the change towards a more Circular Economy (CE). As a reaction to the prevailing economic system of 'take, make, and dispose', the concept of CE aims to create a closed-loop system where resources are conserved and brought back into the lifecycle after being used [2]. Accordingly, manufacturing firms are influential and claimed to be among the most dominant coordinating organization in the world [3] and so any strategy aiming at increasing circularity cannot be pursued without their engagement.

Despite the important role of manufacturers in achieving CE, our theoretical and managerial understanding of how their critical decisions can have implications on a CE, is still limited. This study contributes to the scientific knowledge in this area. We pose that decisions concerning manufacturing can have profound impacts on the entire

product's lifecycle stages, which includes but are not limited to 1) designing products for reusability, recyclability, and remanufacturing; 2) improving the product design with less material use for same service and for durability and longevity and 3) selecting 'cleaner' materials from more environmentally conscious suppliers [4]. Extending the extant body of knowledge, the study identifies and evaluates the most critical decisions across functional areas in manufacturing and their impact on the implementation of CE. Thus, while previous studies tend to focus on the products and/or industries characteristics, the approach used in this study draws on the building blocks of the [Porter's] value chain. Our results show that the overall performance of CE depends on a well-functioning collaboration across the entire firm and conscious management of stakeholders, and hence, only by including the entire lifecycle can manufacturers wholly succeed with implementing CE strategies. Besides, by focusing on manufacturing, this study responds to the call for further research on building a solid base of empirical research on CE in the manufacturing sector [5], hence contributing to literature on CE and manufacturing.

The paper proceeds as follows. Section 2 introduces the '3R principles' main actions of the CE. Section 3 highlights the methodology used in the research, followed by analysis and discussion in section 4. Finally, Section 5 presents the closure and limitation of the study.

2 Circular Economy – the 3R principles

Firm's implementation of CE is mainly perceived through three actions referred to as '3R principles': reduce, reuse, and recycle [6]. The goal of the reduce principle is to minimize the input of primary energy, raw materials, and waste through eco-efficiency. Eco-efficiency refers to the improvement of efficiency in production and the consumption process, by keeping or increasing the value of products while also reducing environmental impacts. This can be achieved by using fewer resources per unit of value produced and by replacing harmful substances in favor of less harmful ones per unit of value produced. The reuse principle mainly covers operations that aim to use again products or components that are not waste for the same purpose for which they are conceived. Lastly, the recycle principle refers to any recovery operation by which waste materials are reprocessed into products, materials, or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

3 Methodology

Our study explores an emerging phenomenon – CE, hence an embedded single-case design was deemed appropriate since it is suitable for revelatory purposes [7]. The case company (hereafter MediX) provides training, educational and therapy products for lifesaving and emergency medical care, with its headquarters located in Scandinavia. MediX was chosen due to their interest in exploring business opportunities under the

circularity logic, where the business model(s) is aligned with either closing, slowing, intensifying, narrowing and/or dematerializing loops. It is, thus, worth mentioning that MediX has not implemented any of the CE strategies yet, rather they are in the process of doing it. Hence, this study aims to identify and evaluate MediX's most critical decisions in manufacturing and how they may impact their implementation of CE in the near future.

To be able to do that, data were collected through semi-structured interviews as well as informal conversational interviews with individual team managers of key functional areas (i.e., product development (PD), software development, strategic sourcing, manufacturing, distribution). The interviews were important as they helped us to detect and hence understand the most critical decisions made within and across all functions. To achieve optimum use of interview time, an interview guide was developed and was organized around a set of predetermined open-ended questions, with additional questions emerging from the dialogue with the involved managers. In so doing, the interviews resembled a dialogical action research approach [8], which helped the researchers to bypass short-term intervention and thus facilitate iterations catalyzing reflective discussions and learning [9]. More so, to gain additional viewpoints on the critical decisions, supplementary sources were collected, and a workshop was conducted, where all teams were present. This served as triangulation and reinforced additional cycles of feed-back and learning.

4 Analysis and discussion

Based on the knowledge obtained through the above learning actions, the data material went through an individual analysis and coding process, which were later presented to all participants to increase accuracy and enhance the validity. This created an additional feedback-loop, which was beneficial for the conclusions drawn. This section discusses the most critical decisions, which are classified into the following: 1) PD decisions, 2) strategic sourcing decisions; 3) manufacturing decisions; 4) customer/user decisions and 5) distribution decisions. Taken together, such decisions provide a mixed picture when it comes to the prospects for circularity. Some of them have aspects that can either enhance or hamper implementation of CE for MediX.

Product development decisions

Inefficient information sharing was identified as a challenge among all the functions, and a critical decision connected to this issue is *when exactly to share information with others.* This was stressed by sourcing, manufacturing, and the distribution functions, and in particular for the PD function, as it is where the production starts. Designers greatly influence the amount of time the sourcing team has to handle a sourcing assignment, since designers usually have the initial responsibility for preparing the technical specifications for firms' products and the materials that go into them. However, designers at MediX, especially in the early phase of designing, are mostly unaware of what exactly they are building, and the materials/parts that may be needed, as such it does not make sense to have the sourcing team on board at that stage. Accordingly, the

designers understand that sharing information with other functions provides adequate visibility, enabling them to make good decisions that can improve the total chain profitability. However, the challenge is when exactly is the right time to share it with the sourcing function, resulting in untimely exchange of information between them.

Consequently, designers play vital role in designing CE-oriented products., as they control what raw materials to use, how to manufacture the products, how the product will be used and how it will perform. Hence, more than three out of four decisions directly influencing materials selection and manufacturing processes are determined in the design phase and over 80% of the environmental costs are determined before the product is even created [10]. As such, decisions made by the PD function play a major role in the shift towards a CE. Thus, if information sharing with other functions is delayed, untimely waste is generated at MediX (e.g., disposal of obsolete parts, rework, and disposal of built prototypes). This can be due to sourcing of parts starting too early, ending up not being used by the designers when done with the prototyping. To support a transition to a CE, it is essential that designers involve sourcing and manufacturing functions in the PD process as early as possible, as that will help firms to better use material and energy efficiency, and hence manage losses. Broadly, lack of collaboration and delay in information sharing can be one of the impediments to MediX's effort to build circular supply networks, as the sourcing may not be able to communicate CE requirements to their own suppliers, much less enforce them. Moreover, since a CE intrinsically requires a systems approach and the involvement of all value chain actors [6], it is crucial that MediX strengthens their internal integration before attempting to integrate themselves with other value chain actors. This supports the contention that information sharing within a firm should precede the information sharing between firms [11]. At the end of the day, it is all about mutual understanding and willingness to give and take (required from all teams), if satisfactory CE solutions are to be reached.

Strategic sourcing decisions

Currently, sourcing decisions are perceived as strategic and have moved up in the hierarchy resulting in decisions being made by managers at prominent positions within firms. MediX is one such firms that have embraced the concept of strategic sourcing, thus, making acquisition decisions with the intent of creating distinctive value and achieving a competitive advantage [12]. Sourcing is helping MediX create value not only by managing costs and availability, but also by collaborating with other supply chain members to improve customer responsiveness, reduce risk, develop innovative products and processes, and market innovations more effectively. Together with the decision regarding where to source from, one of the most critical strategic sourcing decisions for MediX is whether all corporate requirements for a particular part of a product should be fulfilled by one selected supplier or not. Given that more than 50% of the cost of goods sold worldwide is derived from purchased materials, supplier selection is seen as a critical strategic sourcing decision for MediX. This is consistent with [13], who assert that suppliers' capabilities heavily influence a firm's ability to produce a quality product at a reasonable cost and in a timely manner, and that supplier performance is considered one of the crucial determining factors for the firm's success.

These critical decisions imply the nature of the relationship MediX has with their suppliers, which has a significant impact on realizing a CE. In fact, supplier selection is becoming a crucial routine for implementing successful circularity. For instance, the innovative selection criteria go beyond standard features like price, quality, and lead time [14] and include eco-friendly practices, programs, and attitudes [15] Firms are now looking for suppliers that are concerned with environmental issues and are able to provide technically restorative and regenerative materials [16]. Thus, the strategic sourcing function has a role to play in relation to CE 3R principles [17]. For MediX, the reduction principle can be reflected in the function's ability to avoid unnecessary waste, through systematic evaluations of what they need pertaining to the developed specs for their products and the materials that go into them. The function does not directly affect the improvement of efficiency in production and the consumption process, i.e., eco-efficiency, but can ensure that the right parts are available. This would avoid waste in the form of the wrong materials/parts, which usually end up discarded, and can result in fewer parts used per unit of value produced, which is one way of achieving eco-efficiency [6]. Further, the reuse and recycling principles are also relevant to the strategic sourcing function, as it can contribute with evaluation of materials and parts used and provide alternatives that enable a higher degree of reuse and recycling at MediX. The ability to support 3R efforts indicates that the sourcing function can enhance CE implementation; as the function can consider multiple cycles of value creation as well as disposal when the end of life is irreversibly reached, which is especially necessary for MediX in their quest to capitalize on circular practices.

Manufacturing decisions

When deciding whether a manufacturing process is to be executed in-house or externally, the firm's strategy, and the coordination of procurement with other functional strategies, such as logistics and production, should be considered [18]. This explains why the critical decision to *make-or-buy products* at MediX is made by both manufacturing and sourcing functions. In fact, such a decision is the starting point and a vital element in the sourcing process as it determines the number of value-adding activities that potentially can be sourced from suppliers. Although the most common make-or-buy triggers are cost and quality problems [19], for MediX it is mostly due to lack of capacity.

Product quality versus on-time delivery is another critical decision particularly in in-house production. It becomes a critical issue when there are delays, which then pose decisions about whether to compromise on quality and get the new product out on the market on-time. An intriguing question though is whether one have to choose one of them or if these factors can go hand in hand? The latter is what MediX practices. In their case the most important thing is not to compromise on quality when delivering projects on-time, but in case that happens, the decision must be done on a firm level and not restricted to individual decision makers. Indeed, in today's highly competitive market where technological innovation and its growth are significant, both quality and time are essential for the success of their products, and not least for the shift towards a CE. Hence, if quality of products is compromised right from the designing stage, it can result in a product that breaks down before its end of life, which in most cases, is either

financially not viable to repair, or simply not reparable. Consequently, they are discarded and landfilled, creating detrimental environmental consequences with enormous loss of materials, energy, water, and labour embedded in them. Thus, as noted earlier, key lies in how a product is designed.

Customer/user decisions

Customer/user team supports the PD function through understanding customer and user needs at a detailed level by meeting and interacting with them. One of the critical decisions they make is *which user information to forward to the product development function.* As MediX has a large customer base worldwide, there is just too much user information collected. This makes it hard for the customer/user team to decide which of the collected information will be useful in informing the PD decisions. Having said that, both explicit feedbacks provided from users and insight gained by interpreting user behavioral data can provide guidance on how to improve MediX's products, and thus this becomes a critical decision. Indeed, by being thoughtful about the type of user information that would be most valuable for PD or improvements can assist MediX with better decisions and thus serve their users better.

Closely related is the actual *purpose of collecting user data*. This type of decision covers aspect about e.g., data that can assist with discovering designs that provide the best outcomes, and which one would help them determine what work would have the largest impact on users. This might even be essential as explicit feedback can help surface user requirements that firms (in this case MediX) might not have thought of and opportunities to expand their offerings to address specific concerns. Undeniably, knowing the purpose of collecting user data is vital, as that enables gathering of relevant information, and if used wisely, it can give an edge over competitors and increase the impact of limited resources.

Having a deeper knowledge and understanding of customer/user needs enhances customer-focused design thinking, which can help firms to reap more value from the energy and resources they use. Simply put, the transformation to a CE will require fundamental changes in how MediX sells their products as well as how their customers/users buy them. Accordingly, an emphasis on understanding user expectations and levels of acceptability will be key to the success of many CE propositions. For example, offering services rather than products, producing more durable products by using better materials, or designing products for maintainability allowing critical components to be replaced when they wear out. Just as MediX is fully aware about taking a user-centered approach to innovation can create radical change, they know that if they do not understand their users, how then could they expect to design circular products that they aspire to?

Distribution decisions

How to plan distribution properly is a critical decision made by the distribution function. This affects the volume of shipment, as knowing how much to ship depends on the history of how many products have previously been sold, to whom and what versions they were. It takes about six to eight weeks to transport products on a boat from

Scandinavia to US, and the number of products that are sold per week is what is on a boat shipment per week. Thus, the correct shipment with regard to both volume and product type(s) becomes crucial. For instance, if the distribution personnel have missed out and shipped the wrong products, the stock in the US might fail to sell them as they are not purchased/ordered. In such a case, MediX is obliged to ship the right products by airplane. Failure to do so increases the risks additionally, as it would imply another six weeks of waiting, or in worst case scenario missing out on sales. Consequently, when shipping the products to distribution centers, the distribution function must always have a double guess; in terms of what is needed in stock (how much stock) and what exact products are to be sold. Otherwise, any minor error made in the forecasts by MediX will not only affect themselves (in terms of costs) but also their distribution centers, located in Europe, US, and Asia (e.g., stockouts and excess inventory, resulting in less efficient use of storage space, excessive use of transportation and resource waste).

In view of this, it is obvious that MediX still operates the linear model of production, as they produce their products mostly from virgin materials (i.e., except for the metal as it is recycled), and the end products are shipped to their distribution centers all over the world, where they are used, discarded, and eventually replaced by newer versions. This is an untapped potential value, which could be realized through CE implementation. Precisely, MediX could retain the utmost value embedded in products by paying close attention to the production and distribution systems that will enable them to collect and recover used products and/or components besides manufacturing new ones. By doing this, not only is the amount of waste sent to landfills minimized through repair, remanufacturing/reuse and recycling but also leads to considerable energy and economic value savings added to the products in the production phase.

Further, it can also be deduced that MediX struggles with inventory accuracy especially in their distribution centers. To be circular, it is therefore essential to have a complete visibility of what the distribution centers have in stock because inventory accuracy and CE are complementary: without one there cannot be the other [20].

5 Closure

The findings of this study suggest that of all the most critical decisions made by many functions, timely exchange of information is the most critical and yet it often fails to happen. Thus, the emphasis is on the role of time, which is more often than not, an underappreciated dimension in the study of affect at work [21]). Even though the delay in information exchange, for instance, between PD and the strategic sourcing functions at MediX is well substantiated and unintended, such a delay does not only impede work by blocking access to a needed resource, but it can also have substantial negative consequences for CE implementation. This is especially a risk, when overdue information is needed by the strategic sourcing before any further action can be taken (e.g., sourcing parts for the spec).

Additionally, based on our findings, we argue that the 3R principles are not something any function can achieve in isolation, instead it requires collaboration with

various internal functions (holistic approach). Further, the involvement of the sourcing in the design and development stage and collaboration with the manufacturing is of utmost importance. Thus, such an involvement is crucial in ensuring that design changes are communicated effectively to all parties involved as well as a common understanding of what material and components are needed.

While the present study provides valuable insights, it is important to outline some limitations as they provide opportunities for further research. Firstly, the study has identified and evaluated the most critical decisions in manufacturing based on a single case study, hence future studies may further explore the subject based on multiple cases. Secondly, given the increasing recognition to embrace circular economy across different industries, future studies may consider investigating in detail the various managerial issues from different sectors that need to be addressed to assure a successful implementation. Specifically, how managers and stakeholders from different sectors in general and manufacturing in particular can benefit from analyzing the most critical decisions made in their systems.

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