Realizing Value Opportunities for a Circular Economy: Integrating Extended Value Stream Mapping and Value Uncaptured Framework

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Abstract. A shift to a Circular Economy requires more than the implementation of new processes and activities. It also requires identification of new opportunities to create and capture value by analyzing value captured and uncaptured across the product life cycle. However, previous studies focusing on value captured and uncaptured have consistently employed the value uncaptured (VU) framework in isolation. Hence, this study combines the VU framework with extended value stream mapping (EVSM), to identify waste and value improvement opportunities with 'high' circularity. Based on an in-depth case study of a firm that produces patient simulators, both approaches have been applied. The findings of the current study prove the effectiveness of integrating EVSM and the VU framework when firms are to evaluate the possibilities for realizing value opportunities for a circular economy.

Keywords: Extended value stream mapping · Value uncaptured · Value opportunities · Circular Economy

1 Introduction

Manufacturing companies are striving towards more environmentally friendly operations and products, creating an increased need for a balance between environmental aspects and efficiency gains [1]. By integrating and implementing lean thinking and Circular Economy (CE) practices simultaneously, this can be achieved. This synergy is seen as a corollary effect of firms' challenges for rethinking their strategies in order to add more value while contributing to social equity and prevent environmental burdens [2]. Although these concepts differ in their focus, their values and ideology to eliminate waste and create value are comparable – complementing each other in producing effective outcomes, and thus, the coalesce seems natural. Hence, CE presents an ideal solution

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to the current global problems of environmental damages, resource scarcity [3] and to the establishment of a closed-loop economic system. Lean, on the other hand, has been a proven success to eliminate waste and to create value [4] by achieving efficiency and economic benefits. However, despite strong correlation between these concepts, only few attempts have been made in integrating their tools to spark new ideas in the effort to realize the much-anticipated CE within enterprises. Precisely, there is paucity of research on coalescing extended value stream mapping (EVSM), a lean tool, with the value uncaptured (VU) framework, for identifying value opportunities that are regarded as potential solutions to reduce the negative forms of value or to turn them into positive forms of value.

Based hereon, the current study's objective is twofold: 1) identify and evaluate forms of value uncaptured present in different stages of the product's lifecycle, 2) investigate how the identified value uncaptured opportunities can be realised. The obtained knowledge is created in collaboration with a firm that produces patient simulators.

The rest of the paper is structured as follows. Section 2 provides a brief introduction to EVSM, while Sect. 3 focuses on the concept of value uncaptured. The methodology employed is described in Sect. 4, followed by analysis and discussion in Sect. 5. Finally, the closing remarks in Sect. 6 places the findings in context.

2 Extended Value Stream Mapping

Extended Value Stream Mapping (EVSM) can be described as an enterprise improvement methodology capturing firm level details in visualizing the entire (production) process, apprehending material and information flows throughout its timeline [5]. Its aim is about "leaning out" the process from the bottom-up, while realizing process optimization in the targeted business function [6]. Thus, conducting it eases the work of firms to bypass static process optimization improvements. It manages to capture tangible processes in the manufacturing flow and links it with the information flow, while heightening wastes and thus triggers continuous improvements on both intra- and inter-organization level. Accordingly, extended value stream mapping can be applied as a strategic and operational approach that aims at analyzing, capturing, and gaining value across an entire organization [7]. Hence, creating a consensus on what is valuable (i.e., usable) and what is waste is very important for the ideals of CE. Arguably, EVSM echoes the cycles that can be found within a CE context.

3 The Concept of Value Uncaptured

For an organization to move towards circularity, a description of the business and a plan for how it will make profit is necessary and this is commonly referred to as the business model. An effective approach to innovation of sustainable business model is recognizing value captured and value uncaptured and identifying the opportunities represented by value uncaptured (VU) [8]. VU is the benefit delivered to the company and its stakeholders; it does not include only monetary value, but also the wider value provided to the environment and society (e.g., improved energy efficiency and zero emissions). Value uncaptured refers to the potential value that could be captured but has not yet been captured [8]. It exists in almost all companies. Some value uncaptured is visible, for instance, waste streams in production, co-products, and underutilized resources. Most often however, value uncaptured is invisible, e.g., over capacity of labour, insufficient use of expertise and knowledge. Value uncaptured is classified into four forms: 1) value surplus – value which exists but is not required (e.g., unnecessary repeated work); 2) value absence – value which is required but does not exist (e.g., temporary lack of labour); 3) value missed – value which exists and is required, but is not exploited (e.g., inefficient use of human resources) and 4) value destroyed – value with negative outcomes (e.g., pollution, bad working conditions) [8].

4 Methodology

The present study deploys what [9] refer to as action research learning, as the approach corresponds to this paper's objective, which is to evaluate forms of value uncaptured in collaboration with practitioners to create learning opportunities between and among the participants. The case firm (henceforth MediX) develops healthcare-related solutions and programs focused on a common mission of helping save lives. The research presented in this study is restricted to the lifecycle of one of their products, Mani2.0.

In addition to a Gemba walk and several factory visits, data were collected through semi-structured interviews, informal conversational interviews, workshop, and documents. Prior to these activities, an EVSM was conducted together with managers on operational level using MURAL (a digital workplace for visual collaboration). This EVSM was presented during the workshop, where themes and additional research questions were formulated in advance to encourage engagement and discussions. This exercise enabled a comprehension of all the teams' experiences from their point of view, which helped the research team to be aware of potential biases [10]. As such, data collection was not restricted to the activity of 'just collecting data', instead it provided learning opportunities between and across research teams and the involved participants, as new interpretations were co-created during the workshop.

5 Analysis and Discussion

Forms of value uncaptured present in lifecycle stages of Mani2.0. The analysis generated 13 main sources (see Table 1) of VU across Mani2.0's lifecycle, divided between beginning of life (BOL), middle of life (MOL) and end of life (EOL).

Table 1. Main sources of value uncaptured across Mani2.0's lifecycle

BOL	MOL	EOL
Design	Human resources	Refurbish/remanufacture
Sourcing	Operations management	Reuse/redistribute

(*continued*)

Table 1. (*continued*)

BOL	MOL	EOL
Production	Delivery	Recycle
Operations management	Knowledge	
Human resources		
Knowledge and technology		

Value Uncaptured at the Beginning of Life (BOL)

Table 2 illustrates the details of each main source of VU at BOL. In this lifecycle stage, most of the VU was identified in design. This makes sense because it influences the value creation throughout the entire lifecycle of Mani2.0.

Table 2. Main sources of value uncaptured at BOL

Sources	Description
Design	Building “wrong” prototypes; Lack of new design thinking e.g., circularity; Poor communication between designers, purchasers & manufacturers; Discarded built prototypes; Too many/unnecessary iterations; Insufficient and inefficient use of human resources; Use of more time in building prototypes; Overprocessing
Sourcing	Limited procurement of recycled components/materials; Over procurement or too early procurement; Unexploited resources; Inefficient inventory management; Storage waste (increase in space requirements for idle materials)
Production	Limited use of recycled components/materials in the production (all plastic parts are from virgin materials); Re-work
Operations management	Inefficient inter-function collaboration; Inefficient resource sharing
Human resources	Under capacity of designers and software developers; Unused/misused human resources
Knowledge and technology	No reuse of knowledge; Lack of common knowledge base; Tacit knowledge; Lack of technical material know-how; Too many control points in developing software

Considering the various types of VU that exist in design (e.g., *building wrong prototypes*, *lack of new design thinking*, *poor communication between designers, purchasers, and manufacturers*), *iterations (cf. rework and design)*, is the most emphasized. Rework iteration does not help the design evolve towards the intended goal because it focuses on recovering from previous design errors. Design iteration focuses on the evolution of the design toward the desired final state through abstraction levels [11]. Too often, these iterations increase complexity, thereby leading to inefficiency and waste. A good example of rework iterations is *building "wrong" prototypes,* which results in most of them being discarded. Too many/unnecessary iterations are therefore considered to be the root cause of other VU, such as, *unnecessary use of time in building prototypes* and *overprocessing*. Hence, avoiding the causes of rework iterations, as well as performing design iterations without skipping abstraction levels [11] should contribute to solving such problems.

Further, *limited procurement of recycled components/materials* is another type of VU observed in sourcing. This implies that procurement processes and practices at MediX are strongly based on the purchase of goods and services through a linear approach. Other forms of VU in sourcing include *over procurement* or *too early procurement*, *discarding of materials due to obsolescence*, *storage waste* and *inefficient inventory management*. These are partly caused by another form of VU within the same lifecycle stage (i.e., BOL) but in a different function (design – product development), thus, *poor communication between designers, purchasers, manufacturers, and other functions*. The latter is in line with the argument presented by [12], that improved communication leads to efficient inventory management. In a similar line of thought, [13] assert that information sharing alone could provide significant inventory reduction and cost savings to the manufacturer (MediX in this context).

Value Uncaptured at the Middle of Life (MOL)

Table 3 shows the details of each main source of VU at MOL. *Distribution* was regarded as a key VU source at this stage.

Table 3. Main sources of value uncaptured at MOL

Source	Description
Human resources	Inefficient communication between distribution and other functions Lack of human resources
Operations management	Inefficient inter-function collaboration Forecasting problems
Distribution	Shipment of "less demanded" products; Delays in delivery; Inefficient delivery; Lack of circularity design in packaging; Not reusing packaging; Packages are pre-marked with specific product names
Knowledge	Lack of knowledge of the distribution centres

Lack of proper distribution planning is causing unnecessary waste at MediX. Thus, determining the right versions of Mani2.0 to be sent to each distribution centre (DC) to meet customer demand is a challenge. Mostly, products are shipped by boat on a weekly basis to the DCs around the world. However, if the DCs have run out of those versions demanded, then MediX must air transport those products to reach the customers within the contracted timeframe. This leads MediX to question whether it is better to ship the products by boat and have high level of stock in DCs or air the products whenever the customers place orders and have no stock in DCs. To answer this question, there has to be a balance between excessive product stocking and product delay, as the former may result in breakage and waste (in case some products are unsold), while the latter may result in costly labour delays and subsequent time overrun.

CE principles can be applied to manage this excess stock and may help to unlock the value in these products by identifying alternative routes to market, especially in cases where selling them is not possible (due to obsolescence). For example, it may be possible to repurpose some of the components, that is, components can be harvested and sold as spares to facilitate repair or reuse in subsequent generations of Mani2.0. However, this will only be possible if such versions are designed with components that retain the same specification over multiple generations. Hence these can be reclaimed from unsold stock and used in the manufacture of the next line of Mani2.0.

Value Uncaptured at the End of Life (EOL)
At EOL, three main sources of VU were identified (Table 4).

Table 4. Main sources of value uncaptured at EOL

Source	Description
Refurbish/remanufacture	No refurbishment and remanufacturing; Lack of capacity to undertake refurbishment or remanufacturing; No known customer demand for refurbished/remanufactured products; Lack of refurbishment and remanufacturing guidance and methods
Reuse/redistribute	Limited reuse of products/components; Usable products discarded by customers; Small market for used products; No known customer demand for reused products
Recycle	Limited recycling; Low-value disposal of recycled parts; Valuable materials in discarded products

The, *lack of refurbishment/repair and remanufacturing* is caused by value absence in other forms such as *lack of capacity to undertake refurbishment or remanufacturing*. Accordingly, a fundamental tenet of the CE movement is to do more with less, such as, making products last longer through durability, maintainability, and upgradability [14]. Hence, the ability to repair end-of-useful life of Mani2.0 is a powerful tool towards achieving this aspect of a CE.

Besides, MediX focused more on explaining about recycling relative to the other two sources (remanufacture and reuse). Additionally, the recycling they referred to was mostly downcycling, even though they are planning of investing in ‘upcycling’, which is of higher value relative to downcycling, in the near future. This reflects the fact that MediX has not considered value at the EOL stage as important as in the BOL and MOL. This is not surprising, as many manufacturing companies have prioritized recycling despite it being the least value capturing loop of all CE strategies. Regardless, recycling rate, not ‘resale rate’ nor ‘reuse rate’, is still the normative basis for evaluating recovery performance [15].

5.1 Realization of the Identified Value Uncaptured Opportunities

MediX should incorporate CE principles into their production processes, as this would contribute to determine, assess, and manage the environmental and social risks while identifying the economic and environmental benefits of reusing, remanufacturing, and recycling resources. Such effort raises the standard of due diligence and monitoring to support socially and environmentally responsible decision-making. For example, by purchasing recycled and recovered materials/parts to be used as production inputs. Thus, sourcing does not only play a vital role in keeping resources in use for as long as possible to extract their maximum value, but they also respond to customers' demand for firms to deliver social benefits, products, and services with a sense of responsibility or concern for the problems and injustices of society. Another value opportunity is the use of Just-in-Time in procurement. This ensures that the materials/parts are only delivered to MediX when needed and only in the quantities needed, thereby preventing excessive storage of the materials. It would as well prevent waste caused by stockpiling, inefficient handling, and materials/parts leftover [16], which are often discarded due to obsolescence. Moreover, scrap from plastic molding can be re-granulated using a local recycling company. In so doing, MediX is not only protecting the environment, but also reducing carbon footprint by using a local company to provide this service. Also, plastic is a recyclable material, thus, it can be reprocessed and reused, especially since 60% of their Mani2.0 is made of plastic.

Additionally, MediX can maximize value through reusable packaging, which is in fact a preferred interloop activity in a CE today. This implies adoption of returnable packaging, which will not only reduce or eliminate generation of waste at the final customer, minimizing risks to the environment, but also present a better cost-benefit ratio in terms of industrial applications compared to disposable packaging [17]. Just as disposable packaging, returnable packaging has some drawbacks such as transportation costs (direct and reverse), flow management, reception, cleaning, repair, storage, and capital invested. To reduce costs with returnable packaging, one should design and develop reusable packaging that outlast durability performance better than any single use package would. For instance, developing light and resistant packaging, as shipping costs often are linked with the load weight. In this case, the use of standardized returnable packaging is an advantage to optimize the use of space during product transportation and reduce transportation costs [17]. Overall, reusable packaging is not only key to achieving a CE and solving the plastic pollution problem, but equally presents untapped business potential for MediX. Besides, given the nature of Mani2.0 where upgrades are common practice to maintain a high efficiency, MediX may focus on redesigning such products to make them more modular than today. Also, since these products are equipped with advanced software and technology, they are likely to become obsolete. Hence, designing them for effective component/part reuse or recycling (e.g., designing for disassembly) may be the best choice.

6 Closing Remarks

The findings indicate that certain aspects of value creation in current identified waste-activities and resource utilization are neither explored nor exploited favorably. Focus is directed on creating value mainly in design and production (BOL) while missing opportunities to create and capture value when products are in use (MOL) or even at the end of the life cycle (EOL), when recycled or discarded.

Overlaps are observed between some forms, such as value surplus and value missed, and value absence and value destroyed. Additionally, cause-and-effect relationships exist between some value forms across different lifecycle stages and some practices of CE. Some value missed in MOL is caused by value surplus in BOL, for instance, disposal of obsolete Mani2.0 is partly caused by their constant upgrades. This is a common case of cannibalization, as a reduction in sales volume of the older versions of a product is because of the introduction of the newer versions. This leads to obsolescence of many older versions, which reflects MediX's current situation. Hence, embedding CE strategies to the cannibalization process can improve the situation as they increase the maximization of retained value, thus, prolonging the circulation of the products in the economic system, thereby reducing the level of obsolescence. However, such strategies can also lead to imperfect substitution especially when they do not avoid demand and production of new products on a one-to-one basis [18]. On that note, the production of new products is only partly displaced by CE products and thus the overall production increases [19]. These may in fact incentivize MediX to increase durability, standardization, or modularity of their products to facilitate reuse at EOL, while stimulating reuse of the valuable items that are otherwise being left unused in storage or discarded.

Although the study provides some interesting findings, it should be interpreted in the context of the limits inherent in qualitative research, such as the lack of generalizability due to the application of a single case company.

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