Sustainable Production through Advanced Manufacturing, Intelligent Automation and Work Integrated Learning, J. Andersson et al. (Eds.)

doi:10.3233/ATDE240195

Supporting the Transformation to Access-Based Business Models in a Circular Economy with a Practical Model for Calculating the Costs of the Provider

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Abstract. In a transformation to becoming more circular, many original equipment manufacturers (OEMs) are investigating the potential of transferring product ownership from the user to the provider, thus enabling access-based business models. Such a new model also makes the product life cycle cost borne by the provider, meaning that the OEM gains an interest in reducing the life cycle cost and prolonging the life cycle for its own benefit. In this study, a case OEM is in such a transformation and postpones the end-of-life through refurbishment and remanufacturing. However, to launch the access-based business model, the OEM needs to understand its new cash flows. Therefore, the objective of this paper is to show how an OEM has been supported by a model for calculating the product life cycle costs when transforming to an access-based business model. Through applying transdisciplinary research, a calculation model was developed in close collaboration with an OEM to calculate and visualise the product life cycle costs. The study also shows how the remanufacturing cost can be estimated based on existing repair and maintenance data. Furthermore, the importance of developing decision-making insights to persuade upper management that the new circular practices can provide boosted profitability is highlighted.

Keywords. Remanufacturing, refurbishment, assessment, total cost of ownership, circular economy

1. Introduction

As of today, there is a growing interest in reaching more circular operations on a multitude of levels, from supply chains and manufacturing to the products themselves [1–3]. For original equipment manufacturers (OEMs) to shift their resource flows from linear to circular, there is a reliance on adequate business models [4]. These follow various principles to narrow, close, or slow the resource flows [5]. Within the research area of value-retention processes [3], access- and performance-based business models have been shown to be beneficial for OEMs to facilitate easy access to return flows of products [6]. In such business models, the customer gets access to a product, but the

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ownership is retained by the provider – the OEM, in many cases – throughout the product life cycle. These business models are known as product-service systems (PSS) or product-as-a-service (PaaS) [7]. The embedded value of the returned products is then retained through, for example, remanufacturing or refurbishment, and the like-new products are sent for another use cycle [3].

To provide a PaaS is nothing new. Such practices have steadily grown in interest during the last two decades, and even before then, it was a known business practice yet not widely spread [8,9]. For OEMs that have yet to experience access-based business models and value-retention processes, there is often internal inertia when transforming from linear to circular business practices [10]. A main barrier to this adoption is a hesitant mindset and company culture against the transformation to a circular economy (CE). This hesitance is partly due to low virgin material prices, which otherwise promote linear business-as-usual [11]. To overcome this barrier, the financial consequences of the transformation must be investigated, and the benefits must be understood. However, there is a lack of practical models to analyse the financial consequences [12,13]. Therefore, the main objective of this paper is to show how an OEM has been supported by a model for calculating the product life cycle costs when transforming to an access-based business model. The developed model is practical yet captures common aspects of remanufacturing regardless of the products or the sectors, meaning it is expected to be applicable beyond the addressed case. In this study, the OEM's transformation was investigated from a financial perspective, and the body of knowledge is built upon how OEMs can be supported when transforming to access-based business models. By using this case, we exemplify how a proposed access-based business model can be approved at an OEM by developing financial decision-support insights that support and promote the benefits of an access-based business model. This was achieved by developing a simple-to-use and flexible calculation model designed to assess the business model's profitability.

Like other enterprises [14,15], the studied OEM is working towards expanding its sustainability strategy. At the current state, the OEM has started to approach a circular strategy for its existing product portfolio by introducing a circular business model focusing on offering products through an access-based subscription scheme. Here, the customer gets access to products, but the OEM keeps the ownership and performs maintenance throughout the product life cycle. As such, a PaaS is applied. The OEM has a plan for how the circular business model will be implemented. However, since the OEM is profit-driven, it is required to assess the profitability of the new offering before its implementation. Naturally, when introducing a service in addition to a product offering, new types of costs are induced [16]. These costs are added to existing costs, such as manufacturing and forward logistics, thus making the initial costs higher. To realise higher or comparable profitability to traditional one-off sales, there are benefits in retaining the value of the returning products at the end of the use period [3,17]. For example, remanufacturing can retain both the embedded material and energy value of products, hence making it preferable over, for example, recycling [18,19]. However, from a sustainability perspective, considering not only environmental factors but also economic ones, the returning products need to be reprocessed in a way that secures a sufficient return on investments [20]. This was an aspect that interested the OEM. To promote the new business model internally, sufficient insights were needed on whether the new circular business model could provide any value. Even though a lower environmental footprint was expected to be achieved with the new business model, due to higher levels of circular flows and through remanufacturing [21], the OEM needed to stay competitive and profitable in the market to secure its competitiveness long-term.

2. Methods

The research approach applied in this study follows the framework of transdisciplinary research [22], where the OEM representatives and the research team in parallel and iteratively progress towards the same goal but through different sources. See methodical details in Ref. [22]. The goal of the research was to develop resource-efficient and effective solutions working towards a CE. There was a match between the OEM and the researchers in the sense that the OEM had a challenge to solve, and the researchers could develop a solution. To realise the access-based business model as described in the introduction, a calculation model needed to be developed. This was the task of the research team. Throughout the study, 26 interactions (approximately 30 to 60 minutes each) between the research team, that is, the authors of this paper, and the OEM were held in relation to the task. The style of the interactions was primarily semi-structured and partly opportunistic, where each party discussed the progress. The questions raised from the research side were semi-structured and targeted the proposed circular business model, OEM characteristics, and model design.

Using the collected data, an analytical calculation model was developed in a commercial spreadsheet software application (i.e., Microsoft Excel) and presented to the OEM. On the OEM side, the model was used and validated through product expertise and other datasets. It was also used in relation to a remanufacturing pilot to further validate its results. Based on inputs from the OEM, the research team could further develop the model to be more accurate. The findings relate to the progress of the study and what thought process led to different solutions. It also illuminates the internal struggle within the OEM to find means to motivate the positive effects of new ideas related to a CE and shows that the ideas could lead to positive balance sheet outcomes.

3. The calculation model

The approach adopted to calculate the profitability of the access-based business model with value-retention processes in between use phases was as follows: In the first step, the OEM described its products and the proposed circular business model. Here, various aspects of what characterises its business practices, for example, what outputs, such as quality and costs, are of the most importance. This provided an initial indication of the focus of the calculation model. In the end, it was determined that the model should have the capability to calculate the life cycle cost of the new and the old offering during various time frames as well as present the customer's total cost of ownership.

There are many calculation models that have been developed in academia [e.g., 23–26]. However, many of them are difficult to apply in practice [27,28]. There are reasons such as high complexity, low adaptability, and uncertainty in interpreting the output. It is also the case that company characteristics influence how well a model fits. For the case at hand, no suitable model could be found by the authors. Therefore, a new financial assessment model to calculate the aforementioned aspects was developed. Not completely from scratch, however, as inspiration from van Loon and Van Wassenhove [28], van Loon et al. [29], and Yoda et al. [30] about financial assessment models for remanufacturing initiations identified through a literature review were used [See: 13]. The first two groups of authors above were used to create the basis of the calculation model, while the third served as the source to estimate the remanufacturing costs. Additionally, their models were employed to validate the modelling logic. The research project then further developed the models to fit the specific circumstances and available data of the OEM. To identify the input parameters of the calculation model, the list in Figure 1 was shown to the OEM.

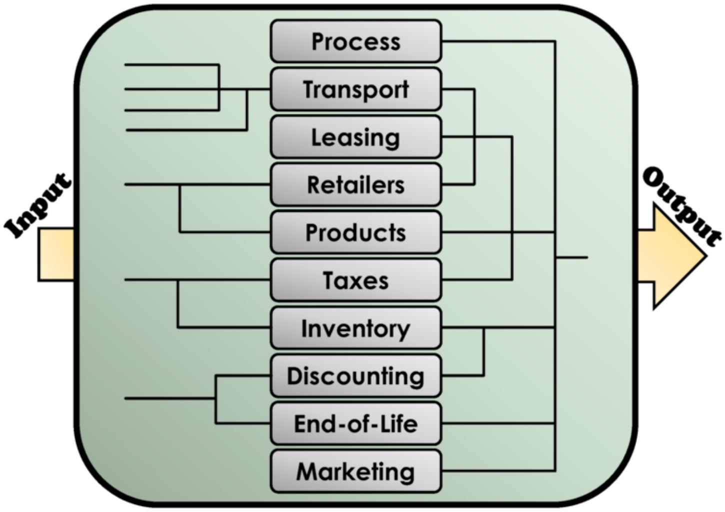

Figure 1. Schematic exemplification of the calculation model and the interconnection of its parameters.

The list is by no means complete, but it provided the OEM with a background of the type of data that should be present to create a reasonable calculation model. In some cases, data was already available, meaning that it could be inserted into the model directly without any modification, while in other cases, certain parameters needed to be derived by the model itself. Let us provide an example: The transportation cost can be calculated with consideration to a multitude of factors, for example, distance, weight, duration, number of middle-hands, warehouse costs, and parcel size [31,32]; see the transport list item and the connections in **Figure 1**, as derived from a literature review on financial assessment models for remanufacturing initiations [13]. However, if a representative value is already available, it can be used instead. Such considerations were discussed with the OEM for all the exemplified parameters and more. This was also one reason why it was difficult to use an already-developed model. Since many of the parameters needed to be tailored for the unique circumstances of the OEM, it was viewed as more time-efficient to take inspiration from existing models and create a new one rather than developing an extension. With these constraints in mind, an approach was taken to make the model highly flexible by making it possible to add calculation modules for future adaptations or circumstances. Simultaneously, the model outputs were discussed as well. As mentioned, the requested outputs were the life cycle cost of the new and existing offerings during various time frames and their total cost of ownership for customers.

The basis of the developed calculation model is shown in **Figure 2**. The model is flexible and adapts depending on the number of PaaS use cycles aimed for. Given a single period, the model assigns the full *manufacturing value* (the first row), no *remanufacturing cost*, and *all recycling costs* and sets potential *residual values* to a lower value. The latter assumes that the product can be resold at the end-of-use and that the PaaS subscription fee only covers product value degradation in the use period. The *manufacturing value* corresponds to the embedded value of the product, for example, the sales price of the product or the manufacturing costs, depending on what the PaaS subscription fee is based on. Note that the *%residual* value here is a percentage that adapts the *manufacturing value* to a new reduced embedded value.

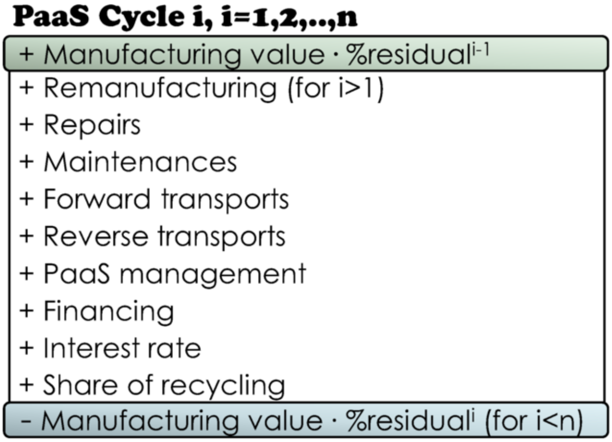

Figure 2. The basis of the calculation model.

If a product is used for multiple use periods, the initial embedded value is reduced by the expected residual percentage. In the model, this value can be varied depending on different periods to consider varied product deterioration rates. Moreover, the remanufacturing cost is covered by the PaaS subscription fee for the second and higher PaaS use cycles. With this model setup, the outputted total PaaS cost decreases as the number of periods increases. Naturally, this assumes that the remanufacturing cost is lower than the embedded value of the preceding use period and that the value of each input is constant between periods; see the last row of **Figure 2**. As part of the model, it is assumed that a product is recycled at the end-of-life stage. Since the last use period should not cover all recycling costs, this parameter is scaled depending on the number of use periods and then assigned equally between the periods. By shifting from selling products traditionally through one-off sales to access-based, a strain is induced on internal cash flows since the revenue flows are spread over an extended period instead of a single, upfront payment. Therefore, it is common to utilise a financial body that secures the cash flows for the product owner [33,34]. Here, the *financing* and the *interest* parameters are costs related to such a body.

Within the model, repair and maintenance costs are directly retrieved from historical data. Linked to this is the number of repairs and maintenance instances occurring during the use phase. These were estimated based on product expert inputs. However, an additional package is planned for the calculation model to consider repair and maintenance intervals that lead to product life cycle cost reductions; see Section 7, – Future research. This also links to the forward and reverse transport costs that occur at every instance of manufacturing, repair, maintenance, and remanufacturing. The model has built-in support to directly scale such factors. Furthermore, one of the most uncertain input parameters is the remanufacturing cost. Since the products of the OEM have primarily been repaired or maintained, there is available data on such measures, but corresponding data for remanufacturing is lacking. Such costs can be estimated through pilots where remanufacturing is performed, but since the OEM had a broad range of products and a limited number of products of varied wear, it was not a valid solution. Therefore, the selected approach was instead to utilise existing repair and maintenance data to derive an estimate of the remanufacturing cost.

4. Estimation of the remanufacturing cost

The available repair and maintenance data consists of the market area, product type, product age, indications of procedures, and costs for labour, components, and utilities. The idea here is to utilise this information to estimate an average product that should be repaired to the extent that it corresponds to a remanufactured or refurbished product. This is similar to the method Yoda et al. [30] applied to estimate the recovery costs for laptops. A component-level reliance was applied to create the estimation. The dataset clearly stated the procurement cost of components, but indirect costs such as labour, repairs, and other maintenance activities (e.g., cleaning and lubricating) could not be directly assigned to specific components. The component-level view was of importance since it would ease the understanding of the model outputs as well as enable the identification of cost drivers. The cost drivers could be targeted when redesigning products to reduce costs. To allocate the indirect costs to the components as cost drivers, a variant of activity-based costing [35] was used. All indirect costs were lined up, and based on product type, the indirect costs were allocated proportionally to the value of the component cost. Hence, components of high value cover a large share of the indirect costs, while a small share deals with low-value components. In this case, it was seen as a fair assumption to make as, on average, expensive components also induce a higher amount of auxiliary work.

This provided an adjusted value corresponding to the cost to repair, maintain, or replace a certain component. However, this value for a component should not occur during every instance of takeback; it should only occur when needed to restore a product to a sufficient quality level. As such, the occurrence frequency of the cost was important. By counting the occurrence of components per instance in the dataset, the probability that a certain component should be reprocessed could be derived. For example, suppose it was identified that component A is listed twice for every instance in the dataset while component B is listed 0.5 times. In that case, it is clear that for every instance of remanufacturing, the same component should occur twice and 0.5 times, respectively. This principle of calculating the frequency of reprocessing a component was then combined with activity-based costing. The result was a representative average of a taken-back product and the cost to refurbish it to a sufficient quality level; see **Figure 3**. In addition, the model had built-in support for other costs related to remanufacturing, which could be added on a case-by-case basis, for example, if certain needed measures were not covered by the dataset.

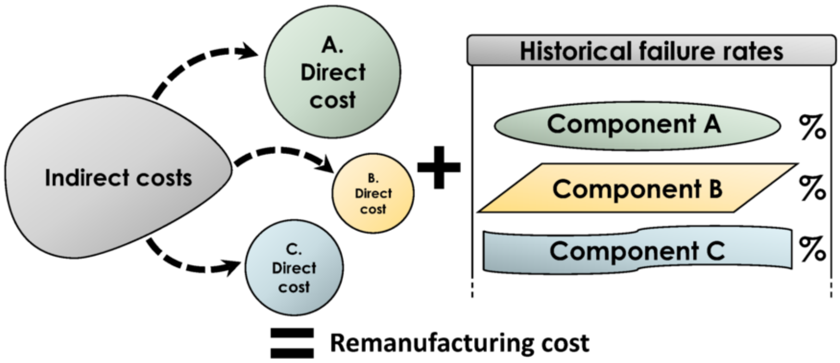

Figure 3. The principle of estimating the remanufacturing cost involves applying activity-based costing. The estimation is realised by allocating indirect costs to direct costs and identifying the frequency with which each component should be replaced.

5. Results and discussion of the model

During the development of the remanufacturing estimation, an alternative approach to primarily counting the occurrence of components per instance in the dataset was investigated. The more straightforward estimation of the frequency is to count how often a component has been reprocessed on a certain product type and then compare it with the number of active products on the market. However, in this case, it was not possible to accurately estimate the number of active products due to the products not being controlled by the OEM. Furthermore, all products that need repair or maintenance work are not returned to an authorised workshop, meaning that components could be reprocessed without being registered in the dataset. Once all the parts of the calculation model were put in place, the OEM used the model as support in the development of the access-based business model with remanufacturing between use periods. One of the main advantages of the model, from the perspective of the OEM, was its capability to provide highly flexible inputs through the spreadsheet software. The OEM could take the base scenario and, with minor effort, change all parameters within the model to investigate different approaches and cost scenarios within the business model. The change from one product type to another was also streamlined, and the model automatically adapted to specific value characteristics for all parameters.

The perspective the model provided to the OEM influenced its view of thinking in terms of circularity. Based on statements of the OEM, previously, there had been a production point of view and focus, but with support from the research team, the business operations could be viewed from the cost of ownership perspective. This is critical when realising access-based business models compared to traditional linear, as the OEM now becomes the product owner throughout the product life cycle [28]. Hence, it also influences the way of thinking. Previously, products were designed primarily for manufacturing efficiency, but now, when there is a return flow of products at the end-of-use stage, products also need to be designed for remanufacturing to ease disassembly, restoration of products, and then reassembly [36]. There is also a higher benefit for the OEM to design products for higher durability as the normal wear and tear costs are allocated towards the OEM instead of the customer [9,36]. If the design of the products could reduce the need for maintenance, repair, and remanufacturing, the OEM can benefit from lower life cycle costs, and the product user can benefit from a higher service level, thus leading to a win-win scenario [37].

Aspects like this were further emphasised during the collaboration with the OEM and the development of the calculation model. The model not only provided an approach to visualise the cash flows of the new business model; it also opened access to interpreting existing repair and maintenance data, thus indicating the major cost drivers to be reduced to reach the win-win scenario. Furthermore, with the use of the calculation model, the lack of certain datasets could also be visualised and could support in determining which further data types should be collected during the use phase. This was on the agenda and highlighted numerous times since the new access-based business model provided the OEM with higher monitoring capabilities during the product life cycle thanks to the retained ownership and new priorities that come with more circular business models such as a PaaS incorporation.

6. Concluding remarks

To summarise the research contribution, there are a multitude of aspects that can be highlighted. The most significant contribution of this research is showing how such a model could be developed and its importance in internally promoting circular access-based business models within OEMs. Even though the new business practice is expected to be more environmentally benign than business-as-usual, upper management requires proof of concept that it is also profitable. Without this, organisational change towards more environmentally benign business practices is unlikely to occur. Thus, it is shown that cost-benefit analysis efforts must continue to reach higher circularity in industry. This finding is not limited to a specific OEM, as the same indications have been seen in several other OEMs undergoing similar shifts towards increased circularity [e.g., 28,38,39]. As such, persuading upper management is vital to spread the usage of circular business practices within OEMs. In relation to the developed financial assessment model, an approach was described on how information was created and transformed into sufficient insights for decision-making. Even though the complete model and used data has not been disclosed here, the logic behind it has been discussed. The study shows the power of a flexible scenario-based tool where values can be adjusted without impacting the pre-set logic of the model. For example, instead of using the calculated remanufacturing cost, the user can manually adjust a value to temporarily override a fixed model parameter, which allows a deeper understanding of its impact on the output. The model was designed to be easily adaptable to fit different company circumstances and data types to reach high applicability. This has been achieved by developing the calculation model in a spreadsheet software, where the inputs are separated from the modelling logic. In this sense, the business model setup can be manipulated without impacting the data, and vice-versa. The approach of applying activity-based costing to estimate the remanufacturing cost **(Figure 3)** is one part of this. With the execution of this study, it is demonstrated how a calculation model can be developed to support the development of access-based business models.

Moreover, the OEM embracement of the financial assessment model further confirms what scholars have already called for [5,27,28]: the need for easily applicable financial models to support the shift towards a circular mode. The simplicity enables the active participation of a multitude of actors with low effort. In this study, this need was also emphasised as it was viewed as more time-efficient to take inspiration from existing models and create a new one rather than extend a current one. The approach of utilising repair and maintenance data to derive estimates of remanufacturing costs also illuminated the importance of such datasets to understand the wear and tear of products during each use period as the shift of burden and ownership is traditionally transferred from the product user to the provider.

7. Future research

The present study took a stance in introducing an access-based business model with reliance on data from linear operations. There is a need to incorporate measures to set an appropriate amount of maintenance to reduce the total costs of remanufacturing and repairs to extend the model and make the remanufacturing, repair, and maintenance costs more accurate, that is, to perform preventive maintenance efficiently and effectively. As such, there is a call for future research in estimating suitable maintenance measures given repair and maintenance data of linear business models. Within the study, there is also planned work to further refine the calculation model and to validate it through other datasets and real-life measurements. Further, comparing and validating the actual costs after the transformation of the company with the costs estimated by the proposed model will be a future task in the long run.

Acknowledgements

This research was supported by the Mistra REES (Resource-Efficient and Effective Solutions) program (Grant No. 2014/16), funded by Mistra (The Swedish Foundation for Strategic Environmental Research). This research is also supported by the SCANDERE (Scaling up a circular economy business model by new design, leaner remanufacturing, and automated material recycling technologies) project granted from the ERA-MIN3 program under grant number 101003575 and funded by VINNOVA, Sweden's Innovation Agency (No. 2022-00070).

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