1. Introduction

The drivers to initiate remanufacturing are broad and range from general factors such as economic, environmental, or policy-related [1] to more specific, including improving brand image [2], reaching new customer segments [3], and lowering the use of material and energy [4]. These drivers tend to benefit original equipment manufacturers (OEMs) that perform remanufacturing of their products. At the end-of-use phase, these discarded or broken products (cores) are restored to like-new condition in an industrial environment [5], and thereby the embedded value of the products is retained for another use cycle through remanufacturing [6].

Despite the potential benefits, roughly only four percent of OEMs in the American and Canadian markets were also remanufacturers [5]. Thus, few OEMs have decided to initiate remanufacturing. The remanufacturing market is in a growth stage and, given prosperous conditions, will potentially triple in size by 2030 [7]. In this growth, OEMs could positively contribute as they can influence product design and develop products suitable for remanufacturing [8] and influence the entire supply chain from raw material suppliers to retailers of finished products [9].

However, when viewing the literature on remanufacturing feasibility [10,11] and decision-making [12,13], there is a lack of guidance specifically for OEMs to follow when initiating remanufacturing. There are decision-support tools for circular offerings on a wide level; see, for example, circular screening and development methods [14,15] and frameworks [16,17]. But for remanufacturing initiations specifically it is lacking, meaning that the hurdles for OEMs to initiate remanufacturing are high. Therefore, to provide insights to fill
this research gap, this paper aims to describe areas investigated during a remanufacturing initiation. The described remanufacturing initiation could provide an inspirational source for other OEMs, leading to a better understanding of which considerations to investigate when initiating remanufacturing. To fulfil the aim, a remanufacturing initiation of an OEM of robotic lawn mowers was studied.

The OEM has a long tradition of manufacturing products with high-quality attributes. These products are sold on a global market through a third-party retail network, but until now, they have not been acquired at the end-of-use phase for remanufacturing purposes. The retail network is well-established and is responsible for sales and supplementary offers such as product support, repair, and service.

2. Case study approach

The applied approach in the study of the OEM initiation was case study research which primarily follows the guidance of Yin [18], where stages of planning, designing, and preparation are conducted when collecting and analysing data. The case study was one part of several concurrent remanufacturing research studies involving the same case company covering aspects of customer perception [19], product design [20], profitability [21,22], and environmental footprint [23]. Together, these studies founded the case company’s remanufacturing strategy and current state [24]. Ultimately, the case received an understanding of its readiness for remanufacturing from a wide range of aspects. In this paper, the progress of the initiation in relation to these studies is described based on the development of the remanufacturing activities and the underlying decision-making.

The data was collected through 88 in-person and voice-call semi- and unstructured interviews with 41 internal and external representatives related to the OEM. The topics of the interviews and the processed data were shared with the OEM for reliance and triangulation purposes [cf. 25]. The data was thematically analysed based on the remanufacturing system consisting of activities to handle the core acquisition, remanufacturing process, and sales activities [26].

3. The considerations of the remanufacturing initiation

In the research study, the case company investigated its prospects of initiating remanufacturing. This initiation was explorative, where each area of the investigation was viewed in relation to the remanufacturing system. In this section, the decisions taken in framing the remanufacturing system in four of the most prioritised areas are described. The considerations are also described regarding a theoretical perspective to judge the reasonability of the case company’s steps during the initiation.

3.1. Select products for remanufacturing

During the remanufacturing initiation at the case company, a product family, that is, the robotic lawn mower, was selected before any other remanufacturing activities were planned. Within the product family, the products are differentiated on their capabilities, installed technologies, and the size of their components, but every product performs the same task (cutting grass) and is visually similar. Due to these similarities, selecting a specific product was conducted concurrently with developing the remanufacturing system. As such, it was possible to select a product compatible with the planned remanufacturing system, thus allowing a smooth entrance to initiating remanufacturing. The criteria recognised during the product selection are found in Table 1.

<table>
<thead>
<tr>
<th>Product selection criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannibalisation</td>
<td>Low overlap with existing product portfolio</td>
</tr>
<tr>
<td>Historical sales volume</td>
<td>Access to many cores</td>
</tr>
<tr>
<td>Residual values</td>
<td>Embedded value worth retaining</td>
</tr>
<tr>
<td>Sales price</td>
<td>Competitive product offering</td>
</tr>
<tr>
<td>Technological modernity</td>
<td>Not technologically obsolete</td>
</tr>
<tr>
<td>Upgradability</td>
<td>Latest technological features</td>
</tr>
</tbody>
</table>

3.2. Develop the remanufacturing process

The remanufacturing process was developed at the case company with the goal of making it as standardised as possible. To achieve this, the remanufacturing process was based on determining a set of components that likely needed to be reprocessed to ensure that the product withholds equal to new standards. This means that the complexity and lead time of the process were kept low by reducing the need for individual assessments and reprocessing of each component. This was also viewed as an approach to reduce uncertainties and variabilities and to satisfy the customer expectations of a premium-classed product. In certain instances, by replacing worn components with new ones, it was ensured that the remanufactured products would perform like new.

In addition to the suggested set of components, further process steps were established to ensure cores reached sufficient quality standards. The considered remanufacturing process covered all steps from receiving a core to having a remanufactured product, for example, storage, cleaning, assembly and disassembly, reprocessing, inspection, and testing. Since the total cost of remanufacturing is influenced by how and what remanufacturing steps are performed [27], the feasibility of the remanufacturing process was primarily assessed from a profitability perspective.

This setup required reliance on an inspection to identify cores able to be restored to the expected standard of remanufactured products given the set of components and the additional remanufacturing process steps. Otherwise, neither a sufficient remanufacturing yield nor a profitable remanufacturing system was achievable. How an inspection process is performed largely depends on the remanufacturing setup [28]. At the case company, there was a high reliance on the transport of cores between different actors; therefore, to prevent buying or transporting cores that cannot be remanufactured, attempts were made to perform the inspection early in the process [cf. 29]. However, since the case study also showed that the acquisition site and...
remanufacturing facility are likely to be located in different areas, it might be necessary to perform an inspection several times; partly to ensure that an accurate assessment has been made at the earlier stage, and partly to gather additional information about the cores during disassembly. The latter is also linked to remanufacturing facilities likely having greater capacity to perform more extensive inspection than an acquisition site at, for example, a retailer based on the availability of advanced equipment and skilled workers.

Furthermore, how the remanufacturability through inspection is assessed varies in practice. For example, Du et al. [30] used a multicriteria analysis for technological, economic, and environmental feasibility, while Galbreth and Blackburn [31] proposed sorting policies. The latter resembles the approach chosen by the case company. Moreover, the remanufacturing process development was also influenced based on the expected quality requirements of the remanufactured products.

3.3. Determine the quality of remanufactured products

A decision was needed on how the remanufactured products are offered, and more so, in relation to the other products within the product family, which customer segments the remanufactured products should target. If the price was chosen appropriately, it was viewed as possible to compete in a way that was previously not possible [cf. 32].

Studies have shown that remanufactured products are usually priced lower than new products [33]. This relates to the customer perception of remanufactured products being lower than new ones, even though the products are, by definition, equivalents [cf. 34]. However, once the market for remanufactured products has reached a mature state, it could be possible to price remanufactured and new products to more equal levels [35]. As of now, however, the case company presumes that remanufactured products must be differentiated by price.

A lower price point means that the margins for achieving highly profitable remanufactured products are strained at the case company. But as Cui et al. [36] showed, a high effort to enable a product fully reach identical-to-new condition often leads to costs that are not backed up by the customers’ increased willingness to pay. Therefore, a similar reasoning was conveyed by the case company. An adequate product that matches new products’ performance and service life but with aesthetical defects at a lower price was perceived as more attractive to customers than a higher price level. It was also said that an aesthetical difference between new and remanufactured products would make it possible to apply a differentiation strategy to lessen the risk for cannibalisation of sales. If the only difference was that remanufactured products were cheaper, it was expected that the customers would always choose the remanufactured product, resulting in substituting new product sales. By having two equivalent products with aesthetical differences, a differentiation between the products could be created to target different segments of customers. The effect on new sales would, in such cases, be lower according to the reasoning of the case company.

By choosing the path of not focusing fully on aesthetics, it was possible to keep the consumption of new materials and components at a low level, which also allowed for the positioning of the remanufactured products at a price level that was considered appropriate. However, this also meant components not considered critical to achieving a service life at least equal to new products were not reprocessed or replaced, meaning that scratches and other minor wear and tear on surfaces were not treated. Due to this, it would be possible to see a visual difference between remanufactured and new products even though they otherwise would operate at an equivalent level. Some of the exterior surfaces of the targeted products, such as chassis, can easily be replaced at a later stage, if necessary or desired by the customer, but at a cost. Replaced chassis can also go to other remanufactured products through cannibalisation. Such practices are common in other industries [e.g., 37,38].

Accepting minor defects made it relevant to investigate pricing based on aesthetical aspects with few classification levels. Since the aesthetic assessment would be a manual ocular process, few classification levels were preferable as it would keep the administrative burden low, and thus also the costs. This is in line with other research studies; see, for example, Wei et al. [39], who considered administrative costs in relation to quality levels, or Nielsen and Larsson [40], who described a four-level quality classification of forklift trucks intended for remanufacturing. Nevertheless, since customers expect that appearance also reflects the value they receive [41], it is reasonable to create classification levels. It was also a question in terms of complexity. It is one task to synchronise one site, but when several are involved, it becomes more difficult to ensure that the quality is equivalent and consistent between the remanufacturing facilities [42]. From this perspective, it was advantageous to consider a few well-defined price classifications or to have only one price point but instead increase the effort into making the products equal. There were perceived advantages and disadvantages of both approaches. How it will be applied at the case company is to be answered once remanufacturing is piloted in practice.

3.4. Perform sales activities

The product selection and remanufacturing process procedures all had roles throughout the study. In addition to these, another set of activities was considered, which includes framing the product offering and ensuring its saleability.

3.4.1. Frame the product offering

Marketing during the study was viewed from several perspectives: To persuade upper management, collaborate with retailers, acquire cores, and sell remanufactured products. In the study, it was not possible to follow how these four types of marketing were conducted by the case company. Therefore, a general approach to framing the product offering at the case company is presented here instead.
We start with describing the persuasion of upper management. During multiple instances, the following saying appeared:

“If we [the case company] do not remanufacture our products, someone else will.”

From a competitiveness perspective, being the first mover has its effects in terms of market and profitability advantages [43]. The case company had seen that a few retailers had begun the process of selling restored second-hand products. This was a step perceived as the early phases of performing independent remanufacturing, that is, a remanufacturer that does not collaborate with the OEM of the core [5]. Given a scenario where remanufacturing of the case company’s products has already been successfully established on the market, the case company perceived that it would be more difficult to initiate remanufacturing because the competition could have added another level of complexity. This is in line with the findings of Allwood et al. [44]. However, just stating that one should pursue remanufacturing to become the first mover is not sufficient; remanufacturing must prove itself as an asset. The financial assessment [21,22] and the environmental assessment [23] showed upper management that remanufacturing could be a part of transitioning to more circular operations while focusing on profitability and environmental values.

The financial perspective of remanufacturing was also used when discussing with retailers whether they would be willing to acquire cores, sell remanufactured products, or perform remanufacturing. Their view was that remanufacturing is interesting if it does not reduce their current profitability. If the absolute sales margin on sales would become lower in comparison to the sales of new products, then it is perceived that they would not be interested. The same analogy applies to the entire remanufacturing system.

The case company also received inspiration from marketing campaigns and remanufacturing offerings of other companies that were publicly accessible online. These companies were not necessarily within the same product segment, but the offering related to their products was perceived as applicable to the case company’s products. For example, a premium car manufacturer provided inspiration for marketing material for remanufactured products, while a household appliance manufacturer gave insights into business-customer relationships, sales contracts, and the differentiation between new and remanufactured products. As such, by imitating the practices of others, insights into what is recognised on the market could be obtained, thus making differentiations feasible [45].

By viewing the tendencies on a market segment basis, the purchasing power of the customers and their perceived scepticism toward products with minor defects were considered. It was discussed whether remanufactured products could be used to expand to new markets where the new products had not been widely sold, partly due to their premium price level. Another electrical and electronic equipment company that remanufactures products with aesthetic defects and a lower sales price was also a source of inspiration. It described how such products more easily could be sold on European markets with a lower-than-average purchasing power. Hence, marketing towards such markets could open opportunities for new customer segments for the case company.

### 3.4.2. Ensure high confidence in remanufactured products

During the remanufacturing initiation, it was highlighted that providing a warranty for the remanufactured products would benefit the case company, as it would show the customer that the products withhold high quality [cf. 46]. The reasoning is if the case company does not believe remanufactured products are durable past the warranty period, why should the customers presume that? Scholars have also indicated that providing a remanufacturing warranty is important for remanufactured products, especially to maintain a high reputation on the market [47].

When preparing the pilot study, the warranty was acknowledged as important early on, but it was not decided until late how it should be offered. Many aspects were handled, for example, warranty length, warranty management during decentralised remanufacturing, and how to keep track of products.

The discussions primarily focused on what warranty length was perceived as appropriate in general terms. In many cases, the warranty length is set to similar durations as new products [33]. Discussions on the advantages and disadvantages of various lengths other than the correlation between costs and warranty length were not held, or such discussions were not revealed to the research team.

It was considered important to involve the retailers during the warranty planning since they were likely to be involved in the sales process of remanufactured products as well as during repair and service work, and in some cases, even remanufacturing. Since decentralised remanufacturing at retailers was investigated, a thorough plan for how the case company could provide a warranty, given a multitude of circumstances, was developed. With a third-party retail network performing decentralised remanufacturing, it is not obvious how the case company could benefit from remanufacturing other than selling spare parts. Even the spare parts would be an issue due to the availability of bootleg versions. Therefore, the warranty provided by the case company was considered an incentive for the retail network to perform remanufacturing according to the specifications of the case company. As such, the decentralised remanufacturing actors must follow the remanufacturing guidelines, use genuine spare parts, and report to the case company. In addition to the provided warranty, the remanufactured products were covered by a certified remanufacturer or approval by the case company classification. Since an OEM stamp is often more attractive from a customer point of view [47], the certification was considered a win-win scenario for the case company and the retail network, leading to expected higher sales margins thanks to increased sales prices and volumes on remanufactured products.
4. Areas investigated in a remanufacturing initiation

The remanufacturing initiation at the case company covered decisions from a wide range of areas. In Section 3, the areas the case company invested the most resources into have been described. For example, the case company’s criteria when selecting products for remanufacturing were covered. In this regard, there are several aspects to consider, such as securing that remanufactured products are sellable on the market even for considerable periods after the new products are released, and prioritising a cost perspective where the case company balances profitability and reaching remanufactured products that are aesthetical equivalents to new products. A cheaper product with minor scratches may be more attractive than a more expensive one with a like-new finish. The case company covered further considerations to find a suitable remanufacturing solution given the circumstances on an internal company level as well as from the customer perspective. The four described areas are presented in Table 2.

Table 2. The factors influencing the remanufacturing initiation at the case company and the framing of the remanufacturing system.

<table>
<thead>
<tr>
<th>Areas of investigation</th>
<th>Factors influencing the remanufacturing system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product selection</td>
<td>A selection of products that do not fix the remanufacturing system to narrow constraints early. Consideration of cannibalisation, historical sales volume, residual values, sales price, technological modernity, and upgradability in relation to cores as well as remanufactured and new products.</td>
</tr>
<tr>
<td>Remanufacturing process</td>
<td>Standardised procedures to reach expected quality standards and keep complexity and lead times low. High focus on inspection to eliminate cores of insufficient condition.</td>
</tr>
<tr>
<td>Product quality</td>
<td>Expected quality of remanufactured products to differentiate and position them in a product portfolio. Focus on performance but less on minor exterior damage (e.g., scratches). A quality output trade-off in relation to effort, cost, and customer expectations.</td>
</tr>
<tr>
<td>Sales activities</td>
<td>Motivate upper management and collaborative partners, e.g., retailers, to approve remanufacturing operations using financial assessments. Other actors act as a source of inspiration on how to position remanufactured products on the market. Warranty offers are important from a product reputation, competitiveness, and collaboration perspective.</td>
</tr>
</tbody>
</table>

5. Concluding remarks

With the presented description of the considerations taken when the case company OEM initiated remanufacturing, a step is taken towards explaining how a remanufacturing initiative could be undertaken. The four areas of investigation here – (1) product selection, (2) remanufacturing process, (3) product quality, and (4) sales activities – provide a glimpse of the decisions the case OEM needed to go through to initiate remanufacturing. In these areas, as seen in Table 2, the case company invested its major efforts during the initiation.

The provided description of the areas of investigation is intended to be used as a source of inspiration for other OEMs. The areas are not intended to be used as a framework or method to support a circular transition [cf. 14,17]. The intention, rather, is to provide insights into how OEMs build knowledge internally and process ideas in relation to common theoretical practice during a remanufacturing initiation. In a scientific setting, this type of knowledge or information is valuable when aggregating descriptions from several companies to specify how remanufacturing should preferably be initiated based on a given set of conditions.

From this case study research, it is indicated that the initiation and development of remanufacturing know-how at a company level are preferably performed from a broad perspective, involving many different perspectives and inputs from several areas of responsibility of both internal and external actors; see the 5AFIR framework [48]. Taking the product selection as an example, the activity appears to be infeasible without viewing remanufacturing from a systems lens to understand how well the remanufactured products would fit within existing product offerings and become a valuable addition to the existing business practices.

Influenced by the importance of a systems perspective in circularity transitions [48], it is also indicated in this research that a remanufacturing initiation rather consists of several parallel and iterative activities than follows a linear process where one activity extends another. This is motivated by one of the research objectives at the start of the project: to create a remanufacturing initiation timeline to identify the order of the activities, that is, the areas of investigation. Hence, the data collected on the progress of the remanufacturing initiation was structured from a timeline perspective. However, the results showed that the remanufacturing initiation at the case company did not follow a linear structure, meaning that the expected timeline could not be created. During the initiation, each area of investigation overlapped and collectively influenced the framing of the remanufacturing system. Therefore, guidelines aiming to support remanufacturing initiations should promote structured low-complexity approaches covering the remanufacturing system as a whole rather than attempting to identify activities and position them in a linear order of priority.

Future research

In this paper, the progress and investigated areas of an OEM remanufacturing initiation were disclosed. This contributed to extending the remanufacturing initiation theory. However, this paper is limited to a certain company and product and thus lacks in generalisability. To ease the remanufacturing initiation for more companies, further research on such initiations for various company types and products is needed. A multitude of remanufacturing initiation descriptions can provide insights into how OEMs should frame or approach their remanufacturing initiations. This would provide a basis to create a structured, systematic remanufacturing initiation framework.

Acknowledgements

The authors would like to thank the Swedish Energy Agency for financing the early stages of the research through
the “Remometer” project, dnr 2019-021532, within the strategic innovation programme RE:Source. The later stages of the research were supported by the Mistra REES (Resource-Efficient and Effective Solutions) programme (Grant No. 2014/16), funded by Mistra (The Swedish Foundation for Strategic Environmental Research).

References


