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Research paper

Between a Rock and a Hard Place. A Case Study on Simplifying the Reverse Logistics of Car Parts to Enable Remanufacturing.

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Abstract

Facilitating reverse logistics is a critical step in achieving a circular economy through remanufacturing and ensuring the recovery of critical raw materials. Despite the importance of these practices, they are currently not commonplace in many product sectors. As an exception, the reverse logistics and remanufacturing of car parts are longstanding but complex practices from which much can be learned to further the circular economy. This paper details learnings from a case study on remanufacturing car parts conducted together with a German (re)manufacturer and a reverse logistics service provider. Co-creation and interviews were utilized to design a digital platform that drastically simplified reverse logistics. The paper highlights the importance of stakeholder engagement and a focus on trust, transparency, and traceability alongside technology and legislation in optimizing reverse logistics. The insights gained from this case study extend to broader implications for the circular economy, emphasizing the role of design in addressing 'soft' factors for successful remanufacturing and the development of effective reverse logistics systems.

Keywords: Co-Creation · Reverse Logistics · Automotive Industry · Remanufacturing · Soft Factors

1. RESEARCH BACKGROUND AND OBJECTIVE

The automotive industry is a critical sector in the EU, accounting for more than 7% of GDP (European Commission, 2023b) and remanufactured car parts play a crucial role in the automotive aftermarket (Prochatzki et al., 2023). Since production costs for new parts strongly increase as demand decreases over time, remanufactured spare parts provide a cost-effective and sustainable alternative for vehicles in need of replacement parts that are no longer in production (Seitz & Peattie, 2004; Wilde et al., 2014).

As the circular economy (CE) gains prominence, the automotive aftermarket presents a compelling case study, especially in light of the EU's proposed new regulations on the right to repair (European Commission, 2023a) and on critical raw materials (European Commission, 2023c). Once the Right to Repair regulation take effect, numerous manufacturers will be obligated to supply spare parts for 5-10 years after production of a product, mirroring the existing practices in the automotive industry where spare parts inventories of 15 years occur (Seitz & Wells, 2006). Likewise, the critical raw materials act will force manufacturers to "increase the reuse of products and components with high critical raw materials recovery potential" (European Commission, 2023c p. 39).

Remanufacturing is a value-retention strategy that extends the service life of products and components, making it an attractive strategy for mitigating critical raw material supply challenges (Gaustad et al., 2018; Wilde et al., 2014), whilst offsetting the environmental and economic costs associated with new production (IPR, 2018). As the automotive industry requires considerable amounts of critical raw materials, in particular given the ongoing decarbonization (Jones et al., 2020; Petavratzi & Gunn, 2023; Zhang et al., 2023) remanufacturing could prove to

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be an enticing opportunity for companies seeking to maintain production capacity and competitiveness (Baars et al., 2021; Bobba et al., 2020).

Despite these opportunities, official publications on the circular economy from EU institutions predominately focus on recycling rather than more resource-efficient strategies such as remanufacturing (Baldassarre & Saveyn, 2023). This highlights a significant research gap in understanding the current challenges of implementing reverse logistics and remanufacturing strategies in the automotive sector. Addressing these challenges will become increasingly important as the transition to E-mobility introduces new components, such as batteries and electric motors, containing expensive, critical materials, with significant social and environmental impacts (Li et al., 2024).

This was the rationale for developing a case study on the opportunities and challenges posed by the automotive aftermarket -a mature market existing since the second world war (Seitz & Peattie, 2004). The case focuses on the German automotive aftermarket where, over the years, the complexity of the reverse logistics of used mechanical car parts (called 'cores') has increased, with more players entering the market resulting in challenges with regard to core acquisition, core storage and core transport (Olugu et al., 2010; Sundin & Dunbäck, 2013). The objective of this case study is to explore how the learnings from this case can be applied to other industries, potentially enabling them to bypass the complexities associated with long-standing but somewhat cumbersome remanufacturing practices in the automotive sector (Fleischmann et al., 2000) and to start closing loops in a circular economy (Ellen MacArthur Foundation, 2013).

To provide a deeper understanding of these remanufacturing practices, the principles underpinning the reverse logistics of cores in the automotive market are described first. One of the major challenges in remanufacturing is a consistent and timely supply of used parts (Guide Jr. & Van Wassenhove, 2009; Seitz & Peattie, 2004). When cores are needed for remanufacturing, they are retrieved from many locations on the market. To keep the reman production process running smoothly, a surcharge system (Kalverkamp & Raabe, 2018) is used; also referred to as deposit system or exchange program. It works as follows:

- When workshops/garages buy a reman spare part, they commonly pay an extra fee (surcharge) on the part. This gives them the 'right to return' a used part (Schlüter et al., 2021).
- After removing the used part from the car, they send it to the same supplier they bought the reman part from.
- This supplier checks the core, gives back the surcharge fee, and sends the core to their supplier. This is a multi-tiered process that crosses various trade levels (see figure 1).
- This cycle continues until the cores reaches the remanufacturer(s) who then makes the final decision on whether the surcharge should be reimbursed. This is based on several assessment criteria, which differ per remanufacturer.

Two types of assessment criteria are commonly used to judge the quality of these cores:

- Technical criteria, such as: Is the right type of part returned? Is there visible damage?
- Surcharge-related criteria, such as: Was the core returned within the pre-set time limit? (the 'core return window') Was the reman part bought there with a surcharge?

If a supplier at some point in this logistics chain decides the core doesn't meet its criteria and rejects it, this creates a problem. For instance, if the remanufacturer rejects the core, the supplier who accepted it earlier has to book a loss for the surcharge because they accepted the core and reimbursed their own customer. This gives the supplier a financial risk and it can strain relationships between the trade levels (Kalverkamp & Raabe, 2018). Figure 1 shows the complexity of the automotive aftermarket with its many trade levels and financial flows accompanying product flows. A more extensive overview of the different stakeholders in each trade levels can be found in Wolk & Nikolic (2022).

The case study described in this paper revolves around a relatively new stakeholder in automotive aftermarket: an independent reverse logistics service provider (henceforth referred to as the service provider) who wanted to address the increasingly complex reverse logistics of cores through a newly developed digital platform. This software tool aimed to support the streamlining of the reverse logistics of automotive cores. Despite their experience handling the reverse logistics of cores, and despite the obvious logistical and economic advantages of such a digital platform, the service provider struggled to generate interest. It was therefore decided to use interviews and co-creation sessions to explore why interest was limited, and how the needs of the different stakeholders in the value chain might be serviced better, helping the development of a reverse logistics system that was favorable for all.

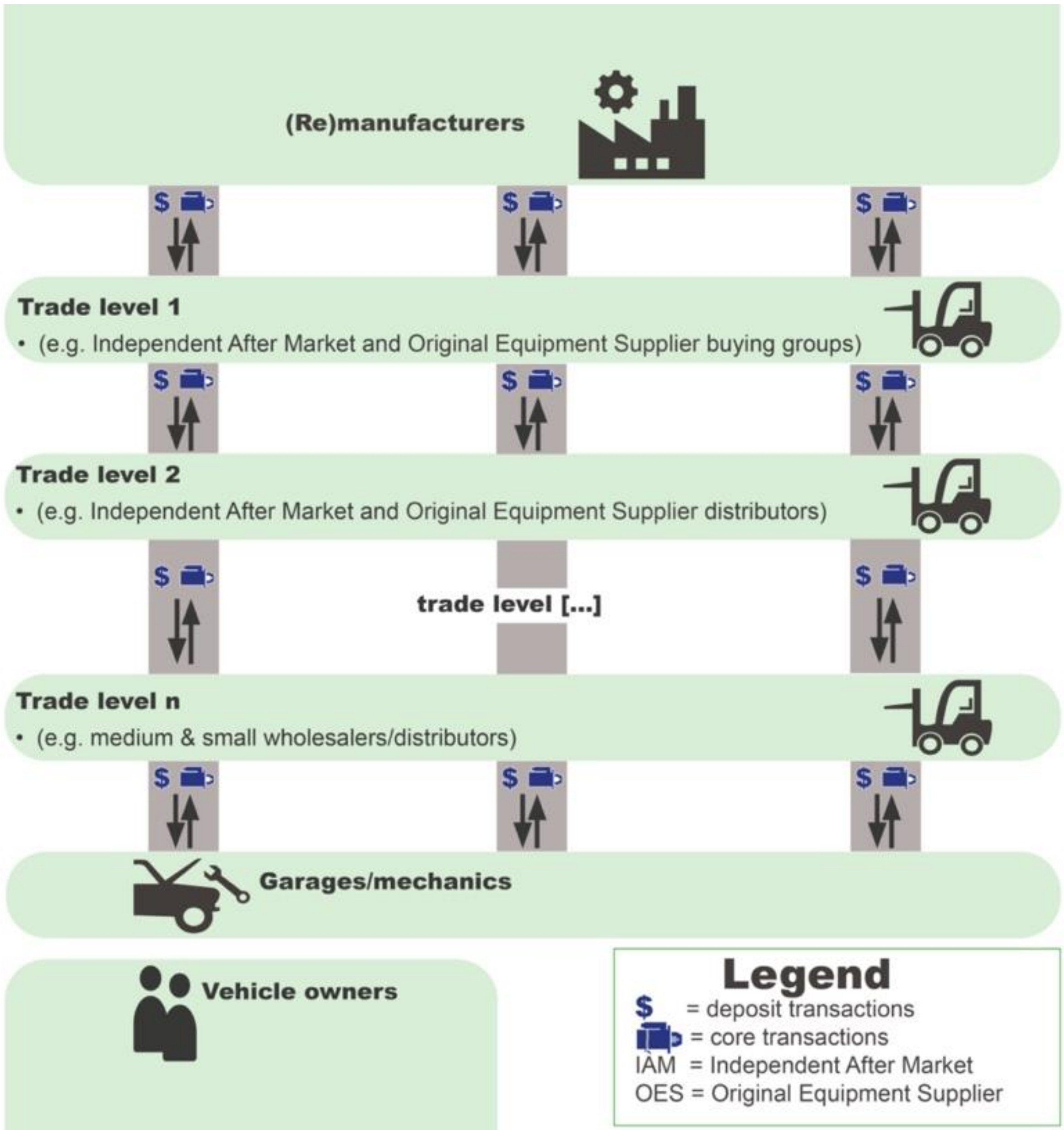

Figure 1. Trade Levels and Flows of Deposit & Core Transactions in the Current Automotive Aftermarket

2. METHODS

Employing case study research allowed the authors to explore the 'how and why' questions related to the implementation of the digital platform. Case studies allow for a contextually rich and in-depth understanding (Yin, 1994), in particular of the "soft" factors essential to this implementation question. The case was chosen for its high practical relevance: the case companies are situated in Germany, which has the largest automotive market in Europe. The expectation was that this case would provide actionable insights for industries with a high dependence on critical raw materials that might be looking to develop, or improve, their remanufacturing activities.

Case study research is ideally suited to deal with complex, real-world situations. To present a thorough industry background and case study results, the theoretical underpinning in this paper is limited to a selective literature review focused on automotive remanufacturing and critical raw materials, as documented in the introduction. Despite focusing on a single case, methodological limitations were mitigated by using multiple sources of evidence, including documents, reports, interviews, and co-creation sessions. Multiple researchers were involved in data collection and analysis to reduce bias and all findings were consistently checked with the participants in the case study, to verify the accuracy of the data and interpretations (Yin, 1994).

1.1 Research Process

Given the challenge of introducing the novel platform concept into a market entrenched in long-standing practices, a method was needed to engage with stakeholders across the value chain. The central approach chosen was co-creation, a qualitative method, well-validated for involving stakeholders in the development process (Holmlid et al., 2015; Roos, 2015; Sanders & Stappers, 2008; van Dam et al., 2021).

Co-creation was initiated by an extensive preparation process. As part of the Horizon 2020 project ReCiPSS (ReCiPSS, 2018), reports detailing scientific literature, best practices in closed-loop supply chains, and a background on the automotive industry (Amir et al., 2019; Oniga et al., 2019), were compiled in collaboration with industry experts. Input from interviews (Klapalová et al., in press) was also incorporated. Throughout this process, multi-day workshops with the ReCiPSS project team were held to identify key stakeholders and prioritize knowledge gaps to investigate further through co-creation.

Subsequently, three co-creation sessions and a series of interviews were conducted. Following the project's completion, an evaluation was carried out with the service provider, as depicted in Figure 2. The case study spanned a period of five years, from 2018 to 2023, which included the Covid 19 pandemic.

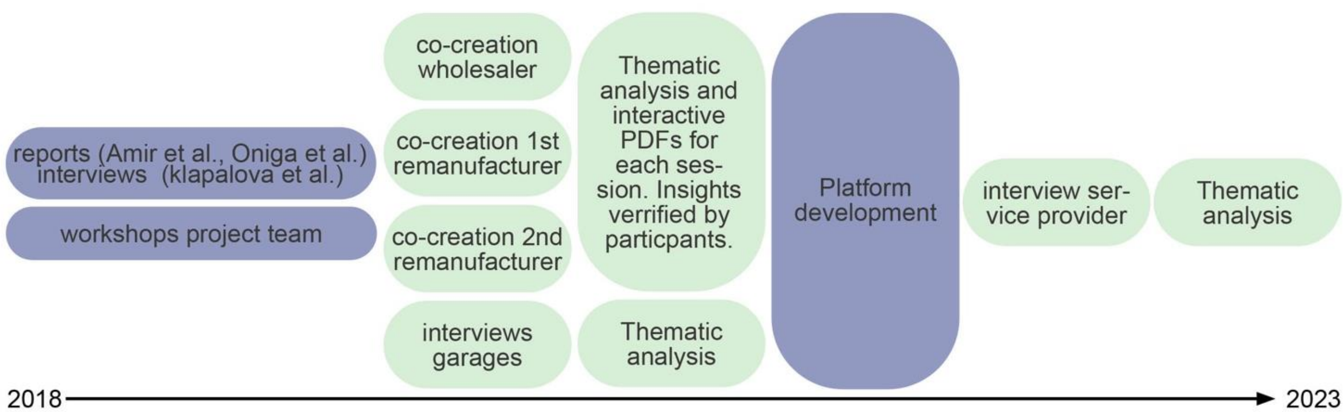

Figure 2. Research Process Flow Diagram. The Blue Boxes Are Not Part of This Paper

2.1 Co-creation

The co-creation sessions were conducted in English between 2020 and 2022. Owning to Covid 19 restrictions and the aftermath, the second and third session were conducted online through Teams. Participants received a set of questions via email a week before the sessions, aimed to 'sensitize' them to the topic (Sleeswijk Visser et al., 2005). The intent was to ensure that questions asked during the session had been preconsidered.

The sessions, designed to understand the participants' current logistics, working methods, processes, and relevant topics surrounding automotive spare parts and cores, included generative exercises in pairs of two or an online whiteboard (Mural) in break-out rooms. These were used to reveal underlying needs, frustrations, and motivations, and ideas participants had to either improve the current situation or create new work processes.

To stimulate discussion, different managerial levels, backgrounds, and experiences were explicitly included in the session. The sessions were moderated by the first author and a research assistant. At least three project members listened in on each session as 'flies on the wall' to prevent bias during data analysis.

Due to the intricate (legal) nature of the automotive market and the differing interests of its stakeholders, sessions predominately focused on individual stakeholders. Mixed sessions that spanned vertically along the supply chain or horizontally across were avoided. Table 1 provides an overview of the companies participating in sessions or interviews, differentiating between original equipment manufacturers (OEMs) such as Ford and Volkswagen, and OEM Tier 1 suppliers (original equipment parts (re)manufacturers that directly supply OEMs). Some OEMs are both vehicle manufacturer as well as parts remanufacturer and are specified as such.

3.1 Interviews

To complete the data set, eight garages were interviewed, offering insights into their perspectives as the initial stage in the reverse supply chain of automotive cores. Challenges arose in organizing in-person co-creation sessions due to geographically dispersion and busy schedules post-Covid-19 economic recovery. Additionally, inexperience with collaborative online meeting tools within this industry made online co-creation sessions impractical. To address these challenges, we opted for online interviews. Interviews varied in duration based on participants' availability. The garages were selected based on their affiliation with the service networks of clients of the service provider (Table 1), ensuring first-hand experience with reman parts. The selection process involved randomly contacting a mix of commercial- and private-vehicles garages who were customers of two reman parts wholesalers in Germany and one in the Netherlands. One additional garage with reman experience from the first author's personal network was also contacted. Garage owners or employees directly involved with the core return process were interviewed, depending on the size of the garage. The interviews, conducted in Dutch and German, were semi structured covering the following topics: the use of reman parts & views on remanufacturing, replacing (reman) mechanical car/truck parts, (financial) incentives, storing, handling and returning cores to suppliers, dealing with scrap parts/cores without return incentives, the amount of effort and type of challenges perceived, as well as areas garages saw for improvement.

4.1 Evaluation with Service Provider

A year after the project's completion, three employees directly involved in the platform development were interviewed to reflect on the platform and service development process. The interviews aimed to capture the impact of stakeholder engagement, and to discuss the benefits and drawbacks of the co-creation approach. The interviewees were a R&D project manager, project manager, and product manager.

Table 1. List of Companies Participating in the Study.

acronym	*Pseudonym and type of company*	*Participated in: (nr of people, date, time)*
WS	Medium sized, family-owned wholesaler	1st co-creation session wholesaler (6pp, May ’19, 4h)
R1	A German (re)manufacturer & Tier 1/direct supplier of OEMs (T1OE1 in appendix)	2nd Co-creation session remanufacturer (8pp, Oct ’20, 4h)
R2	A German (re)manufacturer & Tier 1/direct supplier of OEMs (T1OE2 in appendix)	3rd Co-creation session remanufacturer (5pp, Sept ‘20, 4¾h)
R2	Vice president sales & marketing	70 min interview Jan ‘22
G1	Works at German garage for cars, trucks, and agricultural machinery.	55 min interview Feb ‘22
G2	Works at German garage. Part of R1 service network	45 min interview Feb ‘22
G3	Works at German garage.	60 min interview Feb ‘22
G4	Works at Dutch garage for cars. Part of CarXpert & Bovag network	30 min interview Mar ‘22
G5	Works at independent Dutch garage for cars. Bovag	50 min interview Mar ‘22
G6	Works at Dutch garage for cars. Part of AutoCrew & Bovag network	20 min interview Apr ‘22
G7	Works at Dutch garage for cars. Part of Japanese OE service network	30 min interview Jun ‘22
G8	Works at German garage for trucks	45 min interview Jul ‘22
SP1	R&D project manager of service provider	30 min interview Sept ‘23
SP2	Project manager of service provider	30 min interview Sept ‘23
SP3	product manager of service provider	30 min interview Sept ‘23

4.1 Data Analysis

The recordings were transcribed verbatim, anonymized, translated into English where necessary, and analyzed using thematic analysis (Corbin & Strauss, 1990). Two researchers, both hosts of the co-creation sessions under analysis, examined each co-creation transcript during 1–2-day sessions to ensure interrater reliability. An inductive approach was used to distil overarching themes and topics. Subsequently, transcripts from each theme were re-read, regrouped if necessary, and key statements were highlighted. The themes, topics, and key statements were mapped on a whiteboard to understand the relationships between the different drivers, challenges, and opportunities. This resulted in overviews for each stakeholder of how these elements interplayed and analogies were ideated upon to visualize the interplay. These visualizations were used to create interactive PDFs with expandable text boxes for including relevant participant quotes. Validation and adjustments were made through cross-checking with co-creation session participants. It was not possible to create a similar overview for the eight interviews, due to the absence of a joint session with a collaborative outcome and participant consensus.

The purpose of the interactive PDFs was to convey both graphic visualizations and rich underlying data to the service provider's digital platform development team. In co-creation, it is critical to communicate the insights to those responsible for developing the concept further. Co-creation insights needed to be communicated effectively to facilitate further concept development. Visualizations aimed not only to inform but also inspire idea generation and promote empathy with users (Sleeswijk Visser, 2009). These visuals, including the interactive PDFs, are included in this paper, with the later found in the appendix.

3. RESULTS

3.1 Simplifying Reverse Logistics: Description of Digital Platform

The aim of the digital platform was to simplify the surcharge system by enabling the direct shipment of cores from wholesalers to their ultimate destination, the remanufacturer. This approach would bypass all intermediary trade levels. Cores would only need to be identified and assessed once, thereby reducing overall (remanufacturing) costs. Simultaneously, the platform would diminish the intricacies in financial and product flows, because it would function as a centralized clearinghouse, allocating the value of the transaction to each trade level involved (Figure 2).

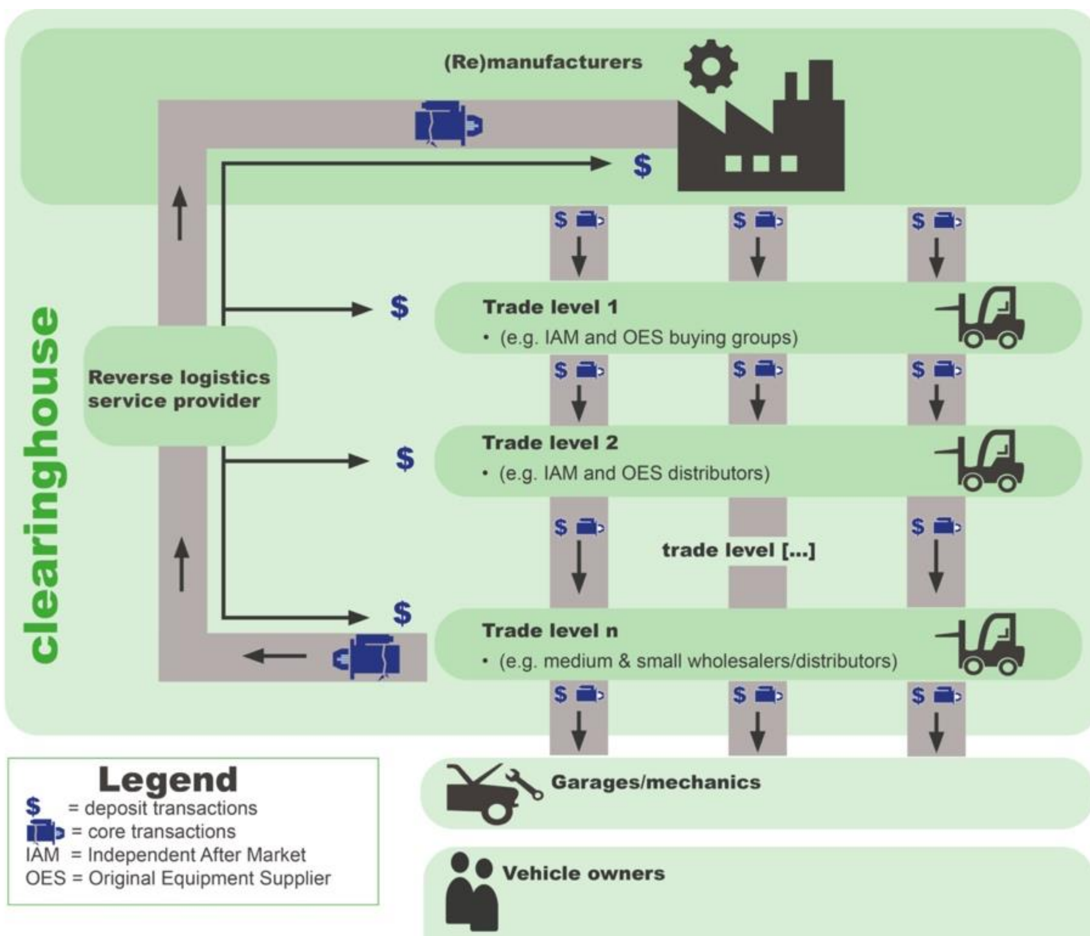

Figure 3. Clearinghouse Concept for the Automotive Aftermarket

An integral component of this digital platform was the introduction of core-return 'options'. These financial instruments granted the holder the right to buy or sell a core at a predetermined price within a specified period.

These core-return options could be transferred and traded independently of the physical product, ensuring trading and settlement processes within the clearinghouse (Oniga et al., 2019). The inception of this concept posed critical questions for the service provider at the project's commencement – would stakeholders embrace the notion of a clearinghouse with options, how would it operate in practice, and what might be potential (legal and financial) implications?

The results of our thematic analysis provided rich insights into the complexity of remanufacturing and the many drivers that enable or constrain remanufacturing, alongside challenges the stakeholders were facing. The results are presented per stakeholder category: wholesalers, remanufactures, and the garages.

3.2 Wholesaler

The wholesaler had 20 suppliers providing a diverse assortment of reman parts with R1 being their largest supplier. The core outflow to the remanufacturers was perceived as problematic because of a perceived lack of transparency and traceability. If a core had been rejected, they had little means to verify the assessment. They assessed they were losing money because not all deposits were being refunded by their supplier while they were expected to refund their own customers. Wholesaler: *"We are doing everything for our customer, they know it and they know we will give them back the money anyway."* It was difficult for the wholesaler to address the problem because it was hard to trace an individual core once it was removed from the car. For example: the article number on the box might not be consistent with the core placed in the box, and matrix codes or other identification marks on the cores might not always be present or readable. Having tried to analyze and optimize their internal processes, they therefore assumed "*it's not us, so it must be them [the remanufacturer]*". This made it difficult for them to trust remanufacturers and resulted in a desire to find ways to control this process better to reduce losses. Wholesaler: *"I would say, don't trust anyone. It is not just us who have that [money loss] problem. It's a problem of the whole market."*

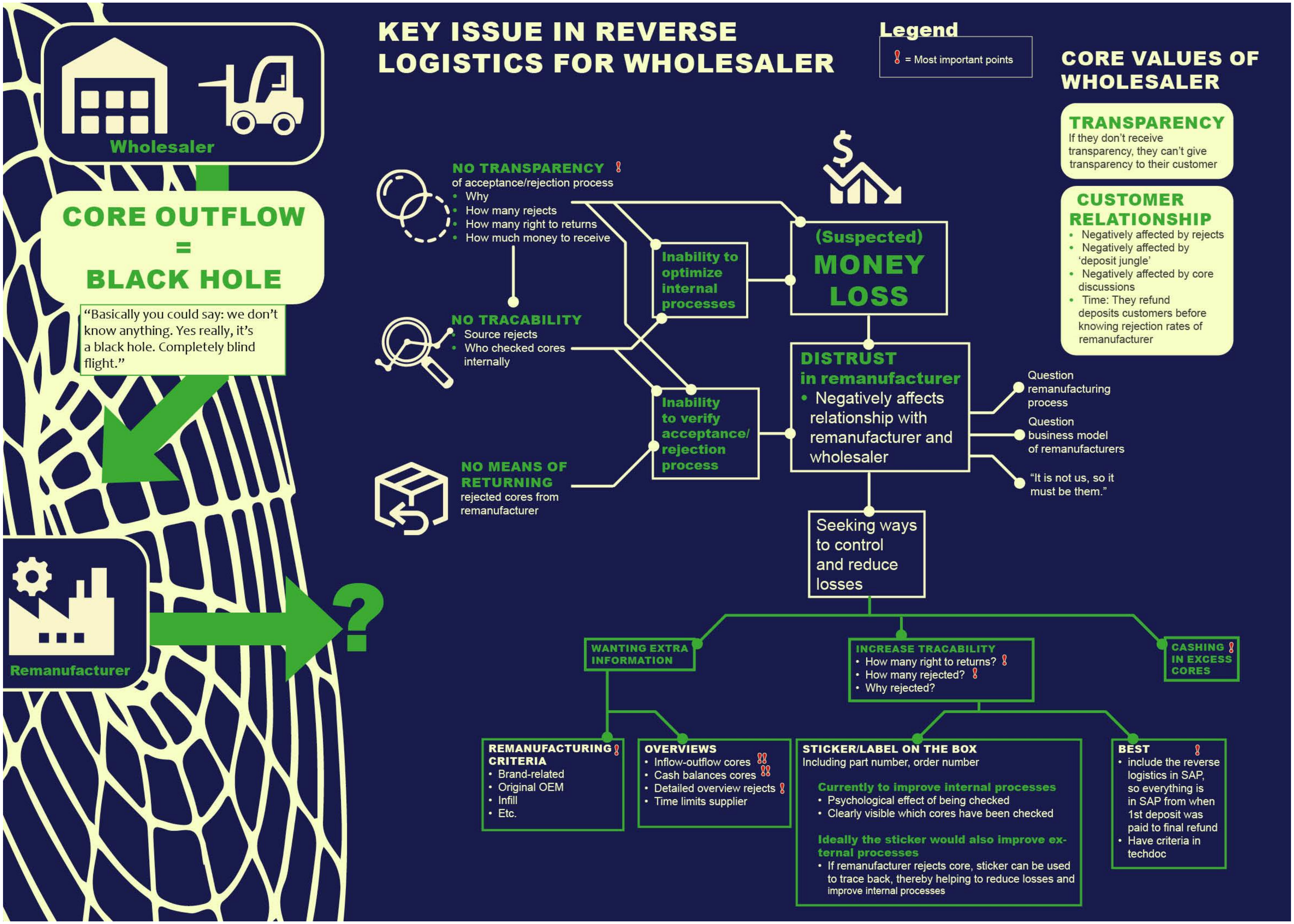

Figure 4. Landscapes of Reverse Logistics of Automotive Cores and the Challenges Faced by the Wholesaler

Figure 4 visualizes the key challenges the wholesaler was facing within the landscape they were operating in. The accompanying quotes can be found in the appendix. The black hole serves as a metaphor for the void experienced by the wholesaler when they returned cores to the remanufacturer, a result of the absence of feedback and transparency in their interactions. Key findings from the co-creation session with the wholesaler were that trust, transparency, and traceability are crucial elements in the setup of reverse logistics services.

3.3 Remanufacturers R1 and R2

The co-creation session with R1 and R2 revealed the complexity in being able to successfully remanufacture but also identified several opportunities. Both R1 and R2 dealt with a variety of used mechanical vehicle parts and had a strong focus on process efficiency. The companies recognized the importance of ensuring that safe and high-quality cores are returned by customers and used for remanufacturing. However, there were differences in how they enforced core quality. R1 has strict core return criteria, resulting in discussions with customers who did not understand why their surcharges were not refunded: *"the customer does not understand why we're not taking it back because it looks fine, it's good, it's not broken, it's not corroded – not that much, and he says, pay me my money. Big discussion."* R2 was less strict in enforcing core quality: *"We are not that strict as it is written inside our core [return criteria documents]"* They were only strict in case customers have been flagged repeatedly because a too high percentage of cores has been rejected. Both remanufacturers recognized the challenges related to the ease of returns for customers. They acknowledged that returning cores required a lot of procedural effort and know-how from their customers, creating barriers to buying reman parts. They also highlighted the time-window within which cores must be returned as undesirable for customers.

Additionally, both companies faced difficulties in incentivizing core returns without creating drawbacks for their customers. R1 and R2 both (partially) use surcharge systems to encourage core returns, but they acknowledged that this approach had its limitations. The surcharge system led to extensive capital binding for customers with accompanying uncertainties concerning whether surcharges would be refunded. They however felt there wasn't really an alternative that ensured a steady flow of cores. Nevertheless, both remanufacturers felt they had a strong relationship with their customers, despite the issues mentioned above. They both perceived themselves as reputable brands and reliable, loyal partners. While the remanufacturers valued trust and transparency, R2 was a step ahead through their implementation of a 'high attention analysis'. It included a process of automatically identifying customers at core sorting stations, taking pictures of rejected cores, and sending these to the customers. This increased transparency, improved customer's trust in the assessment, and improved the quality of cores returned by the customers while maintaining clemency.

There were also notable differences between R1 and R2. For instance, their perspective on legislation. R1 placed a strong emphasis on international legislation and standardization as essential to the protection of the remanufacturing industry. They identified variations in V.A.T. between countries, country-specific legal barriers, and different reman standards as challenges that created an unequal playing field. While R2 did agree with some of these, for instance concerning V.A.T. and country-specific legal barriers such as 'altteile steuer' (a German tax on cores), they were less focused than R1 on international legal barriers. This could be in part due to their position in the market. Additionally, R1 perceived (Chinese) copies of spare parts as a larger threat to their customer base, while R2 highlighted the challenges of outsourcing core management by their large customers, which created more distance in customer relationships.

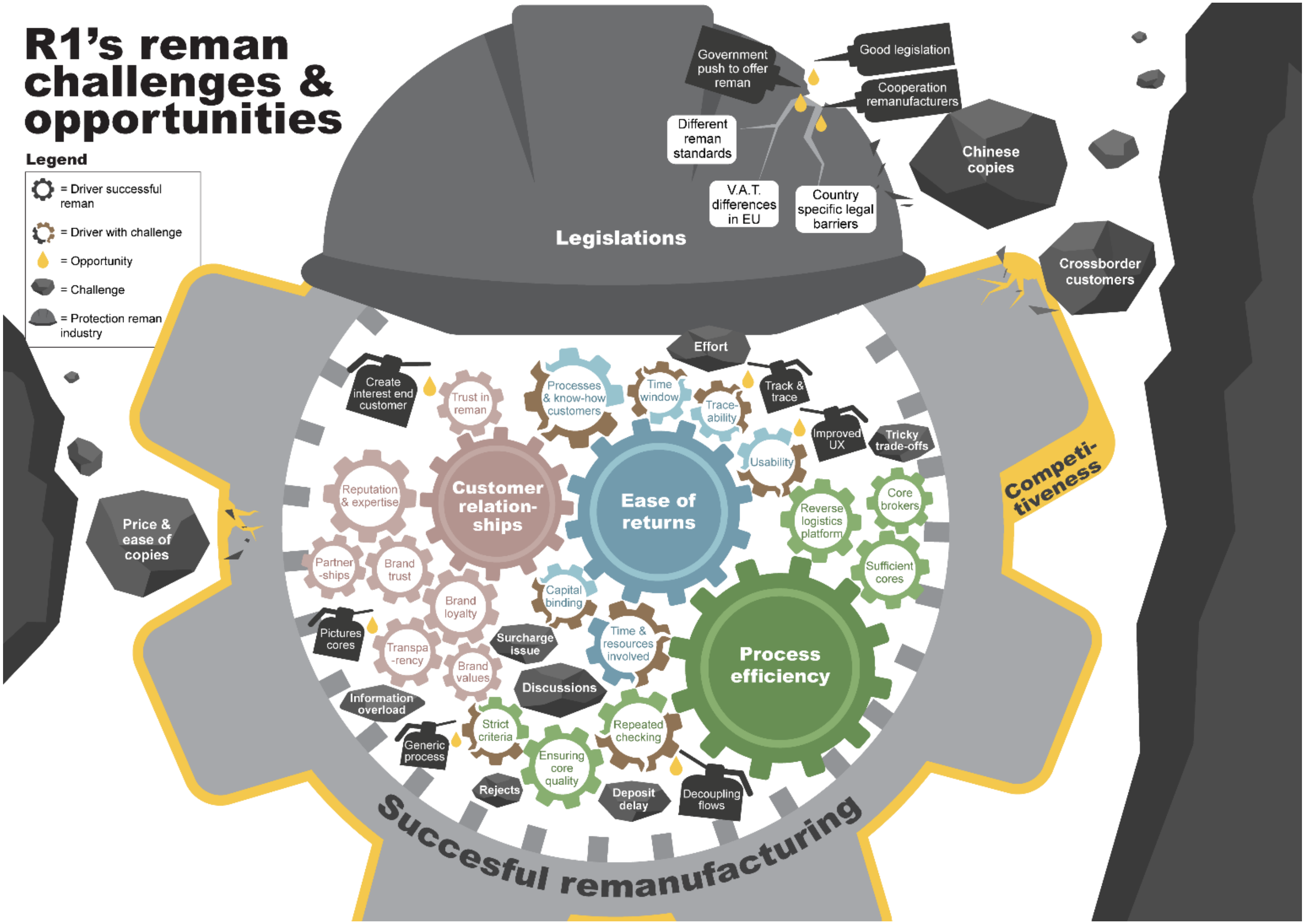

Figure 5. Remanufacturer R1's (T1OE1's) Reman Challenges and Opportunities

To be able to grasp this complexity and portray the results in a comprehensible manner, figure 5 was developed, using a metaphor of a well-oiled machine with interlocking cogs, where rocks cause friction, oil makes the successful-remanufacturing-machine run smoothly, and a hard-hat gives protection (Figure 5). The cogs represent drivers that enable remanufacturing, with three key drivers identified during the co-creation session: process efficiency, the ease with which customers can return cores, and close customer relationships. These three drivers are dependent on numerous auxiliary drivers that also interlock. Some drivers functioned well but others less so, and these are visualized as broken cogs. There were also challenges that caused friction in the system, which are visualized as rocks and external challenges which chip away at the competitiveness of reman parts. The opportunities identified during the session are visualized as oil cans. R1 strongly believed that legislation was essential for the protection of the reman industry and this was visualized as a hardhat, which however currently contains several cracks that need to be glued -a different metaphor for an opportunity. A second visualization was developed for R2 which is part of the appendix.

3.4 Garages G1-G8

Garages are the starting point for the reverse logistics of cores. The eight interviews that were conducted in Germany and the Netherlands complemented the insights that were gathered through the co-creation sessions and gave additional perspectives that are discussed in the following paragraphs.

Garages indicate that the amount of effort it takes to return a core differs per wholesaler, with some garages perceiving the return process as more cumbersome than others. G4 just sees it "*as part of the job*" and not as a lot of effort, while G8 indicates that "*the effort is very high*". G7 describes the process they had to go through with one of their wholesalers as a "*discouragement policy"*: *"You first have to go to the invoice, then you have to make a return request. It must be approved [by the remanufacturer]. Then I have to make a return label and then I have to fill in a return label. And I also have to enter the return -that is a long number- in the system. Well, eventually I get a code*". He found the procedures with his other wholesaler far easier. G5 indicates that he chose his main supplier based on being able to return cores without having to *"crawl behind the computer"* to request a return label: *"That's already a reason for me. I'll order from that other supplier, because then I can just throw it in that container. Easier to do."* All this shows the lack of a standardized core return processes, with each garage developing its own preferred suppliers and procedures for dealing with cores.

Despite the difficulties negotiating the core return process, the garages indicated they rarely have rejects. Garage G5 says about one wholesaler: *"They just take everything, and they will probably count a loss."*, while a different wholesaler is described as having *"military precision. […] If you don't do it completely according to the rules, well, there is a chance that you will not get your deposit back."* This may indicate that certain wholesalers try to attract customers with customer- and user-friendly policies. It is however remarkable how different the rules are for returning cores, reflecting again the lack of a standard approach across suppliers and remanufacturers in the field. Occasionally a core is rejected by a wholesaler because the box is wrong, missing, or damaged, or because the time window within which cores must be returned has closed. The length of the time window however varies per type of core and per wholesaler (ranging from 30 days to over a year), as does the strictness with which this is enforced.

In general, garages seem to be fine with the surcharge system. Credit notes are generally quickly settled by the wholesaler and the garages seem to trust the settlement of surcharge balances.

The use of reman parts varied widely per garage and the perception of how this has changed in time also differed. G6 indicated that core returns for remanufacturing have drastically decreased over the years: *"it rarely or never happens that something is returned."* because exchange products *"are not being offered in the catalogue"* of his main wholesaler. Others buy whatever is readily available the quickest and at the best price. Reman then often seems to have the overhand over new: G4 *"The cost is indeed important; we often work with older cars"* and G1: *"remanufactured parts are far more available than new parts are now [since Covid 19]."*

3.5 Impact on Platform and Service Design

The insights from engaging with stakeholders, and particularly the wholesaler session, strongly influenced the platform service development. SP1: *"[co-creation] was really a game changer for us to understand really the needs and thoughts of wholesalers in comparison to what we had assumed or imagined."* Collaborating with the wholesaler took them into new (service) design directions. Central to these developments was the emphasis on transparency, which became a core element of both the platform and its associated services in the handling of core logistics and financial settlements. Achieving transparency was accomplished by offering digital services that included detailed information on each individual part number received by the service provider. This information encompassed the condition and surcharge value of these parts, empowering wholesalers in their day-to-day business operations.

Furthermore, the digital services provided to wholesalers gave them transparency on what they had sold to their garages, and in turn what core return rights the garages have towards the wholesaler. The insights from the garages helped inform the development of these services to the wholesalers, since in the clearing house, cores are collected from the wholesaler.

4. DISCUSSION

This paper has sought to provide rich insights into commonly overlooked challenges in the reverse logistics of used car parts, uncovered through the co-creation process. In this section, we delve into these ‘soft’ aspect (Boorsma et al., 2022), addressing both their influence on the platform development and insights that can be derived for the broader remanufacturing industry, dependency on critical raw materials, and the circular economy. Table 2 lists eleven main insights derived from the results and the stakeholder who experienced these challenges. In the subsequent discussion, we specifically focus on four ‘T’s’: trust, transparency, traceability, and (digital) technology as well as legislation and the role of design in enabling a smoother transition to a circular economy.

Table 2. List of Insights and Their Implications (WS = Wholesaler, R = Remanufacturer, G = Garage)

Main challenges	**Experienced by:**			**Effect on platform development and service provider**	**Insights for reman practices and CE**
	WS	R	G		
Insufficient attention for stakeholder engagement	x	x	x	Co-creation was a game changer: shifted focus of platform development	Stakeholder engagement is crucial, which can be stimulated through, for instance, co-creation.
Distrust between stakeholders in supply chain	x			Co-creation and independence of service provider facilitated trust	Invest in developing trustful relationships in reverse logistics
Influence core return and surcharge on customer relationships	x	x	x	Developed information flows that facilitated WS's relationships	Gain understanding of divergent interests and find common ground
Incentivizing core return is necessary but has drawbacks	x	x		Better information and creation of 'options' for more flexibility	Consider & address benefits and drawbacks of (financial) incentives
Reverse logistics for reman require high effort	x	x	x	Benefits clearing house reducing steps in reverse logistics confirmed	Minimizing effort for reverse logistics is paramount to successful remanufacturing
Lack of standard approach for core return	x		x	Platform giving standardized approach for customers	Agreements in value chain for standard approaches is beneficial
Too little (financial) transparency on core returns and rejects	x		x	Detailed information on individual parts received by the service provider.	Strive to give right amount of transparency
Difficult to trace cores	x			Provided information to WS at part number level	Consider reman already during part design and use informative code on parts
Inefficient processes hamper successful remanufacturing		x		Confirmed that clearing house can contribute to process efficiency	Consider clearing house or other solutions to simplify reverse logistics

Cheap copies hinder reman		x		-	Legislation should aim to create a level playing field or discourage copies
Legislation hinders some stakeholders		x		-	Attention for legislation that (dis)enables reman

4.1 Trust

Wholesalers, operating as intermediaries in the reverse logistics system of automotive cores, are stuck between a rock and a hard place. They have to navigate relationships with both their customers and suppliers, while simultaneously trying to prevent costs stemming from non-refundable deposits. The research presented in this paper teaches us that any industry interested in improving its existing remanufacturing operations, or in setting up a new remanufacturing division, should emphasize establishing trust among the various stakeholders. Emphasizing trust, especially with intermediaries, is paramount to dispel potential or lingering suspicions regarding core deposit discrepancies. Literature does address the need for trust in stakeholder relationships within the reman industry (Kalverkamp, 2018; Lind et al., 2014; Östlin et al., 2008), and the contribution of co-creation to building trust in B2B settings has also been well documented, for instance by Franklin & Marshall (2019). However, it is remarkable that there is a lack of research into the development of trustful relationships across the reverse logistics value chain and the factors that facilitate trust. The development of the digital platform by an independent service provider, as well as the co-creation sessions by an external party with no affiliations to the industry, emerged as a gateway to building trustful relationships and reflecting these in the services offered by the digital clearinghouse.

4.2 Transparency

This research found that transparency is an important precursor for trust. Stakeholders within the value chain held differing perceptions regarding the transparency they offered or received. Identifying these disparities, points of friction, and conflicting interests proved crucial in the development of a successful service. The clearinghouse concept was strategically adapted to promoted transparency through the information flows towards aftermarket participants, particular wholesalers, to enhance the effectiveness of the financial incentives. Providing transparency is particularly important in this type of situation where financial incentives, such as deposits, are involved, but it is important to employ transparency strategically to avoid overwhelming stakeholders with excessive information. When executed correctly, strategic transparency can foster trust among various parties involved and streamline the complexities of the reverse logistics process, ultimately reducing the effort required.

Furthermore, while the lack of a standard procedure for core assessment and returns may be understandable with the large number of stakeholders operating on the market, in the end this doesn't benefit the automotive aftermarket or remanufacturing in general. A clearinghouse can go a long way to standardizing the return process for all stakeholders, as core assessment and returns are handled by only one party with centralized information on acceptance criteria.

4.3 Traceability

Traceability is closely linked to transparency and is likewise a precursor to trust. Enabling traceability of cores that is workable and practical for all stakeholders in the supply chain is paramount. A complex situation arose in the automotive aftermarket that, to protect used parts during transport, they are sent back in the box the new part arrived in. Part numbers of the cores, if still present and readable, no longer align with part and order numbers on the box. For intermediary trade levels, aligning original order numbers of parts with credit notes received for deposits of returned cores is important.

Likewise, to promote traceability and scale up remanufacturing, enabling correct core identification is important. Effective traceability can massively decrease the effort involved as each individual core is packed, transported, stored, unpacked, manually assessed, repacked, transported further, unpacked again, reassess, etc. This constitutes an enormous amount of work and results in considerable financial losses along the way. This underscores the labor-intensive nature of the reverse logistics process (with dependencies on appropriately skilled personnel) (Klenk et al., 2022), which can make scaling up remanufacturing challenging. A critical element to traceability is incorporating a code on the part that remains readable and gives relevant and appropriate information for all stakeholders, not just the manufacturer. Traceability as well as remanufacturing potential should be considered from the onset of the design. It should be clear which parts are interchangeable and therefore still valuable for remanufacturing, despite (small) updates to the design. Traceability is also increasingly relevant for prioritizing parts containing critical raw materials for remanufacturing (European Commission, 2023c) and beyond that to enable the reuse and recycling of critical raw materials (Koppelaar et al., 2023). Our findings align with broader research efforts to consider remanufacturing from the onset (Prochatzki et al., 2023; Seitz & Peattie, 2004) and incorporate AI (Schlüter et al., 2021) and digital product passports (Adisorn et al., 2021) to improve traceability.

4.4 Technology

The use of digital technology can help streamline reverse logistics processes and facilitate trust and transparency. The case study focused on a digital clearinghouse, but there are other examples in literature where for instance the use of AI, digital product passports, block chain, etc, (Adisorn et al., 2021; Schlüter et al., 2021) could help make reman more profitable. However, it is essential to be mindful of the energy consumption of these technologies and weigh whether the energy required for these solutions are justified (Sedlmeir et al., 2020). Despite the potential benefits these systems offer, they may not effectively address the challenges that the remanufacturing market faces if the specific needs of stakeholders and their context are not taken into account. The lesson learned in this research is that the 'soft' factors should never be neglected when developing and implementing such systems.

4.5 Legislation

Legislation can further support the simplification of reverse logistics and demand for reman. Policy frameworks should prioritize addressing complexities in cross-border reverse logistics systems and avoid taxation schemes for used parts. While the global demand for remanufactured products is still strong (Research and Markets, 2022), the interviews with garages gave some indication that reman is becoming less preferred in certain markets. It is therefore crucial that legislation not only stimulates remanufacturing efforts but also ensures a level playing field. Such regulations should consider the environmental impact and critical raw material demand of reman parts compared to copy parts. This could be achieved through mechanisms like a CO_2 tax (van Dam et al., 2020) or mandatory material declarations (Koppelaar et al., 2023). With proper legislation in place, design for remanufacturing can gain more traction (Prochatzki et al., 2023).

4.6 Role of Design

Furthermore, design can maximize the full circularity potential of remanufacturing and have impact on multiple levels. Firstly, design can ensure longevity and easy remanufacturing of products through early stage design decisions (Ijomah et al., 2007). Such a design/engineering approach can contribute to alleviating critical raw materials problems. Unfortunately, the role of design tends to be largely overlooked by policy makers, who prefer to focus on more 'tangible' metrics like mining and recycling (European Commission, 2023c). Secondly, a design approach like co-creation can act as a lubricant to enhance trust among stakeholders and ensure a smoother collaboration throughout the value chain with better remanufacturing results, as described in this case study.

5. CONCLUSION

Remanufacturing extends the service life of products and components and is an attractive circular strategy for mitigating critical raw material supply challenges. However, reverse logistics and remanufacturing systems will always require more effort than a linear take-make-waste model. Stakeholders in all trade levels in this case study acknowledged the effort involved in the reverse logistics of cores for remanufacturing. Minimizing effort is therefore crucial for successfully scaling up the circular economy. This case study explored ways to simplify the reverse logistics of automotive cores through a digital clearinghouse. The main finding is that stakeholder engagement (understanding the needs and challenges of stakeholders) when developing and implementing solutions is essential. Through the co-creation process that was followed in this case, valuable insights were gained into the 'soft' aspects that are fundamental to the success of a simplified reverse logistics system for remanufacturing. While the clearing house was a solution for the exceptionally complex automotive aftermarket, simpler solutions may be suitable for less complex industry settings. Nevertheless, investing in the four T's: trust, transparency, traceability, and technology, will always be needed. The research highlights, for instance, that incentivizing the return of used goods is essential to maintain a consistent supply for remanufacturing, but that it is important to anticipate and address the drawbacks and limitations associated with accompanying financial flows. Additionally, the research shows the importance of integrating considerations for remanufacturing opportunities and critical raw materials in the design phase. Legislation, such as CO_2 taxes, also needs to be considered to minimize effort and create a level playing field.

There are some limitations to the case study. It primarily centered on Germany within the EU market and, as a result, it may highlight issues that might not be applicable across the whole automotive aftermarket. For instance, in France, legislation mandates that garages must offer used parts to car owners. This may alter the acceptance of remanufactured parts and influence the dynamics between garage and their suppliers. Additionally, outside of Europe and North America, the automotive remanufacturing market may present distinctly different challenges due to the presence of a significant informal remanufacturing industry. Future research should therefore also focus on the dynamics surrounding reverse logistics and remanufacturing in other countries. More research is also needed on factors that facilitate trust and its key components -transparency and traceability- in reverse logistics supply chains.

This research bridges the gap between theory and practice. It offers practical insights for businesses regarding the importance of trust- and transparency-building efforts through stakeholder engagement as well as considering remanufacturing from the onset of the design phase. Businesses can leverage insights from the research to advocate for supportive legislation that stimulates remanufacturing efforts. Simultaneously, the paper contributes to advancing theoretical knowledge within the academic community, emphasizing the importance of addressing 'soft' factors and design to facilitate remanufacturing which can help reduce dependency on critical raw materials.

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AUTHOR CONTRIBUTIONS

Sonja van Dam: data gathering & analysis, visualization (together with student assistants), methodology, writing original draft.
Conny Bakker: funding acquisition, supervision, review and editing

DECLARATIONS

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APPENDIX

For the appendix with the full-sized infographics and their explanations, click here or paste the following on your URL bar: http://circulareconomyjournal.org/wp-content/uploads/2024/10/Appendix_-van_Dam_and_Bakker_between-a-rock-and-a-hard-place-a-case-study-on-simplifying-the-reverse-logistics-of-car-parts-to-enable-remanufacturing.pdf

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