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Exploring inter-organizational relationships in automotive component remanufacturing

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Abstract

One of the industry sectors with the longest history in remanufacturing is the automotive industry. Remanufactured parts include brake calipers, engines, servo pumps and alternators. A big challenge for automotive component remanufacturers is to achieve a steady flow of cores (parts that are used for remanufacturing). This flow could be secured by making agreements with core suppliers, such as an original equipment manufacturer (OEM), a core broker or another actor in the market. The remanufacturer can also choose to collect the cores without closer collaboration with the core suppliers. One crucial aspect in choosing how to collect the cores is that it has to be lucrative.

The aim of this paper is to explore how remanufacturers manage their inter-organizational relationships in the closed-loop supply chain. A case study was conducted within the European research project 'CAN-REMAN', and empirical data was collected from six participating companies within the project, all European small and medium-sized (SME) remanufacturers of automotive components. These companies were investigated, and their relationships, defined in earlier research with core suppliers, were evaluated.

A key finding of the research is that the most problematic parameter with supplier relationships is to receive the ordered quantity of cores from the supplier. This parameter is continually ranked as one of the most important, and the participating companies also claim to have problems with it. A successful relationship and take-back system was pointed out by one of the companies to never be the owner of the actual cores, and only perform the remanufacturing activity (service) for an OEM. This new relationship, called *reman-contract,* is where the OEM owns the core and the remanufacturer just performs remanufacturing including some sorting and storing. It was found that with this kind of relationship, the ordered quantity of cores was fulfilled to a higher degree, and thus the challenge of achieving a steady flow of cores was met.

Keywords: Reverse logistics; Reverse supply chain; Remanufacturing; Automotive; SME; Inter-organizational; CAN-REMAN

Background

Remanufacturing is an industrial process whereby used/broken-down products (or components) - referred to as 'cores' - are restored to useful life [1]. Remanufacturing means that a product is reprocessed or upgraded in an industrial process. During this process, the core passes through a number of remanufacturing operations, e.g. *inspection*, *cleaning*, *disassembly*, *part reprocessing*, *reassembly* and *testing*, to ensure it meets the desired product standards [2].

The remanufacturing business in the automotive aftermarket has existed for a long time, but in recent years has become more interesting due to higher consciousness of environmental issues and directives from the European Union such as the end-of-life vehicles (ELV) directive. The ELV directive was proposed to decrease the amount of waste in the automotive industry by increasing the percentage of a car's weight that has to be reused; in the year 2000, 75% of the car's weight was reused, while in 2015, the aim is to reuse 95% [3].

A fairly new and interesting area within remanufacturing in the automotive industry concerns mechatronics (e.g. power steering systems, central locking systems and anti-lock braking systems) and electronic systems (e.g. engine control units and distance control units) communicating *via* a controller area network (CAN) bus. These kinds of CAN bus components were also the focus in the research project called 'CAN-REMAN,' of which this research is a part. The purpose of CAN-REMAN was to develop innovative diagnosis methods and technologies for automotive mechatronic and electronic remanufacturing and investigate the closed-loop supply chain; in other words, how the collection systems of cores are formed in the participating companies today [4]. The project, funded by the European Union, was conducted by Bayreuth University (Germany), Linköping University (Sweden), the University of Applied Sciences Coburg (Germany), the Fraunhofer Project Group Process Innovation (Germany) and eight European small and medium-sized enterprises (SMEs).

When the work on this study was initiated, interviews had already been completed and data collected at five of the six remanufacturers participating in the CAN-REMAN project. These interviews are reported in Dunbäck and Sundin [5,6]. Based on these interviews, four different types of core suppliers were identified:

- Original equipment manufacturer (OEM),
- Independent car dealerships (ICDS),
- Core brokers, and
- Scrap yards.

These four kinds of core suppliers and their relationships to the remanufacturing companies will be further investigated in this study.

The aim of this paper is to explore how remanufacturers of automotive components in Europe manage their inter-organizational relationships in the reverse supply chain, and to identify which parameters are important to determine the efficiency of the relationships with their suppliers.

Previous research on relationships in a closed-loop supply chain

There are three main activities for a remanufacturer: the collection of cores, the remanufacturing process and the redistribution of remanufactured products [7]. As this paper addresses the relationships between remanufacturer and core supplier, it is the collection of cores that will be in focus. One of the biggest challenges when collecting cores is to manage the quantity, timing and quality of returns [8]. This theory is supported by Fleischmann et al. [9], who state that returns are dependent on the former user's requirements, and not the remanufacturer's. Geyer and Jackson [10] argue that there is limited access to end-of-life products in the closed-loop supply chain, and therefore also for remanufacturers. This, together with Wit and Meyer's [11] argument that no firm can be autarchic and must collaborate with other firms, makes it interesting to study how remanufacturers, being a firm, collaborate with their suppliers of cores.

According to Östlin et al. [12], there are seven different types of common relationships between a remanufacturer and a customer or supplier. Östlin et al. [12] have identified the following relationships within a closed-loop supply chain: *ownership-based*, *service-contract*, *direct-order*, *deposit-based*, *credit-based*, *buy-back* and *voluntary-based*. The level of relationship focus and core control varies between the relationships, as shown in Table 1.

Table 1 Relationships identified by Östlin et al. [12]

Relationship	Description
1. Ownership-based	The manufacturer owns the product and leases it to a customer; the manufacturer often provides service for the product, including remanufacturing.
2. Service-contract	The customer owns the product but the manufacturer performs service on it.
3. Direct-order	One core is sent to a remanufacturer; after it has been remanufactured, the exact same core is returned to the customer.
4. Deposit-based	The customer must return a similar core to be allowed to purchase a remanufactured one.
5. Credit-based	The customer receives a credit when returning a core that can be used for future purchases.
6. Buy-back	The remanufacturer simply buys the cores needed.
7. Voluntary-based	Cores are given to the remanufacturer.

Table 2 Overview of the case companies

Company	Country	Empl.	Annual turnover [M€]	Type of company	Main products
A	Germany	100	14	Independent remanufacturer	Cylinder heads, engine parts
B	Germany	24	1.6	Independent remanufacturer	Alternators, starters
C	Germany	80	4	Contracted/independent remanufacturer	Gear boxes, engines
D	Germany	80	13	Contracted/independent remanufacturer	Engines, powertrains
E	Sweden	130	7.4	Contracted/independent remanufacturer	Brake calipers, diesel particulate filters
F	Spain	64	-	Independent remanufacturer	Diesel pumps, injectors and gearboxes

This study will focus on the seven relationships that remanufacturers have with the four kinds of suppliers further described in the 'Description of core suppliers' section: OEMs, independent car dealerships (ICDS), scrap yards and core brokers.

Previous interviews made in the CAN-REMAN project were used to complement the information. The employees contacted were plant and logistics managers with several years of experiences at the companies. An overview of the participating companies in the CAN-REMAN project can be seen in Table 2 and in Figure 1, where information about size and products is described. The company labels A to E are the same as in Dunbäck and Sundin [5,6], and refer to the same specific companies.

In Table 3, the survey status is presented, as well as which sources of data were used for each case company. The total amount of data in the study was considered to be sufficient to facilitate the exploring nature of this paper.

Figure 1 Examples of products that the companies are remanufacturing. From left to right: a brake caliper, a gearbox and an alternator (from HowStuffWorks© [13]).

Table 3 Survey status

Company	Questionnaire	Interviewed by authors	Interviewed in 'CAN REMAN'
A	Yes	No	Yes
B	No	Yes	Yes
C	Yes	No	Yes
D	No	No	Yes
E	Yes	Yes	Yes
F	Yes	Yes	No

In addition, these case companies were collaborated with during the CAN-REMAN project from a more reverse engineering perspective, as described by Freiberger et al. [4].

Closed-loop supply chain relationships for a remanufacturer

A number of relationships have been identified in the closed-loop supply chain in the case study, as shown in Figure 2. Here, relationship denotes *an exchange of cores between two actors*.

Starting with the end customer in the upper left corner of Figure 2, a core could travel several ways back into the closed-loop supply chain. One way could be that the end customer chooses to go to a licensed or independent repair shop, and from there, the core is delivered to the remanufacturer. Another way could be from scrapping, where the core could be sent directly from the scrap yard to the remanufacturer, or pass through a core broker.

In our study, the Original Equipment Service (OES) is the service organization associated with the OEM. The OES and OEM are highly interconnected, and are therefore linked in the dotted square in Figure 2. The OES in the automotive industry consists of

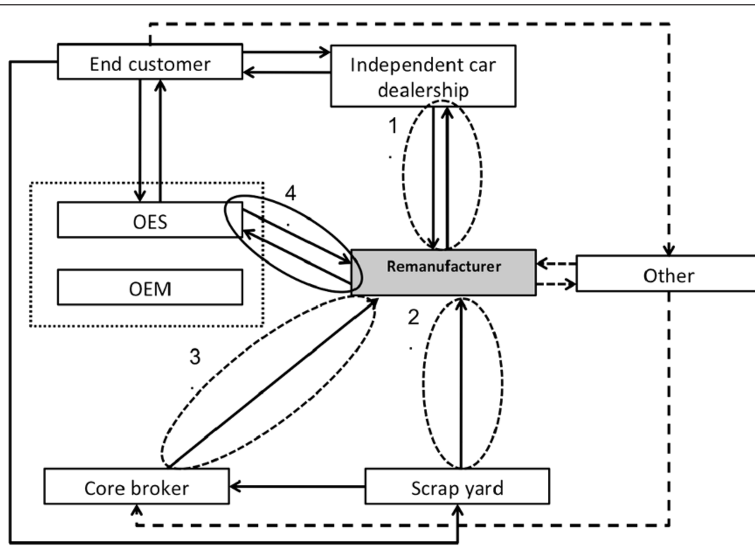


Figure 2 Relationships identified between actors in a closed-loop supply chain.

the dealership network and licensed mechanics, and thus makes up a part of the aftermarket. *Other* could be another kind of actor that has not been identified in this study.

The circles numbered 1 to 3 in Figure 2 contain only relationships defined by Östlin et al. [12]; meanwhile, circle 4 also includes a relationship that does not fit directly into their definitions, which will be further developed in the following chapter.

Description of core suppliers

Each case company was asked to list what relationship they generally *have* with each of the four types of suppliers, what kind of relationship they *would like to have*, and thereafter to evaluate a few specific relationships. The types of core suppliers were (numbers corresponding to the circles indicated with the same numbers in Figure 2):

1. *Independent car dealership (ICDS).* It was shown that with this type of supplier, remanufacturers generally have a deposit-based take-back system, and sometimes also a credit-based or buy-back system. What they would like to have is a deposit-based or direct-order take-back system. Direct-order relationships have been evaluated specifically, and there are no reported difficulties with variation in lead-time or problems with the geographical location, and the purchasing prices are generally lower than from other suppliers. The delivery performance is not satisfactory, which means the remanufacturer does not receive what is ordered.
2. *Scrap yard.* A common relationship that a remanufacturer has to scrap yards is buy-back systems; what they would also like to have are buy-back and take-back systems.
3. *Core broker.* The most common relationship that remanufacturers generally have with their core broker suppliers is of the buy-back type, and this is the relationship they also wish to have with this kind of supplier. From the specifically evaluated relationships with core brokers, the biggest problem seems to be the delivery performance, with some indications that the quantity delivered may vary more than 50% from what was actually ordered. There are no clear results as to whether the purchasing prices from core brokers generally are lower or higher than other suppliers.
4. *OEM/OES.* The main partner for a remanufacturer in a relationship with this actor is the OES organization, and it is from them that cores are sent and received. An interesting relationship identified between a remanufacturer and the OEM/OES is the case where the OEM owns the cores at all times, and the remanufacturer executes the remanufacturing activity. Furthermore, the remanufacturer has to sort out remanufacturable cores from what is delivered, and store remanufactured as well as non-remanufactured cores in the inventory. The OEM, however, performs all other activities such as collection, transportation and to some degree sorting. It is reminiscent of the ownership-based relationship, but a better name would be *reman-contract*. Another common relationship is the direct-order. From the specific supplier evaluations, it can be concluded that the least important parameter is the geographical position. It seems like most OEMs supply the remanufacturer with the right quantity of cores; the supply is regular without variation. Many of the case companies also report that the average purchasing price is lower than from other suppliers.

An interesting aspect of the *reman-contract* relationship investigated in this study is that the remanufacturer itself has come up with the idea and unique knowledge. The idea was presented to several OEMs, and thereafter developed what could be called an industry standard in the automotive industry with this specific remanufacturing process. The advantage for the remanufacturer is that it is not necessary to tie up capital in owning the cores; a disadvantage is that cores may not arrive sorted, and it is unsure how long the remanufactured cores have to be stored before the OEMs demand them back. It is shown that this relationship is successful and that the remanufacturer is content to work like this. In this *reman-contract* relationship, the remanufacturer provides the service of remanufacturing the OEMs' used/broken-down products (cores).

Further, it is shown that in 75% of the evaluated relationships with core brokers, the correct quantity is not delivered, while in relationships with the OEM, 50% is delivered correctly. A reason for this was e.g. that the suppliers could not provide the remanufacturers with more cores. Hence, the remanufacturer needed to negotiate with its customer or buy in new spare parts to fulfil the customer order. This reduces the profits of the remanufacturers.

Advantages and disadvantages of the relationships in CAN-REMAN

This section intends to summarize the most important advantages and disadvantages with the different kinds of relationships that a remanufacturer can have with its suppliers. Since it has been shown that the most common relationships for the companies within CAN-REMAN have been *reman-contract*, *buy-back* and *deposit-based*, these three relationships will be discussed. There will also be a discussion of whether or not an independent remanufacturer should collaborate with an OEM.

Reman-contract relationship

As stated earlier, a reman-contract relationship with an OEM has many advantages. Since a major problem and difficulty for a remanufacturer is to obtain a steady flow of cores, it may be a good idea to collaborate with OEMs in a reman-contract relationship, since the OEM provides the remanufacturer with the desired cores and the remanufacturer does not have to look for cores. It has been shown that this does not remove the problem entirely, since the delivery performance of the OEM, within the CAN-REMAN companies, is just as bad as from other suppliers. Another disadvantage is that some OEMs do not sort the cores before sending them to the remanufacturer's facility, which means that the remanufacturer has to sort out the cores that can be remanufactured from those that cannot. Having a reman-contract relationship could be very comfortable, since many otherwise necessary activities could be omitted, but may also be very resource-intensive, since, as Daugherty et al. [14] state, a lot of commitment needs to be achieved to set up the relationship. Also, keeping the remanufacturing lead-times in the contract could sometimes be hard due to the condition of the cores and their individual parts. If well-considered and carefully thought out before setting up the relationship, long-term success could be created as Daugherty et al. [14] claim, and the risk that a partner acts in a way that causes negative consequences could be avoided [15].

Buy-back relationship

In this investigation, it has been shown that Company F, a company that does all of its purchasing in buy-back relationships, is satisfied having this kind of relationship; it does not experience problems obtaining a steady flow of cores. However, some other remanufacturers that use the buy-back relationship only for complementary reasons, such as Company C and Company E, have experienced problems getting a steady flow. Company F has a better relation and trusts its suppliers and therefore gets a steadier flow of cores. The remanufacturers that purchase in a buy-back relationship only for complementary reasons do not commit themselves to their suppliers. These remanufacturers use what Spekman et al. [15] describe as competition-driven purchasing; this could lead to diminishing delivery performance, which also has been shown in this study, and could be one of the reasons that the delivery performance is so poor. On the other hand, it is more flexible to only buy cores when needed since there are no further commitments when the cores are paid for and delivered. A disadvantage found with the buy-back system in this investigation is that the independent remanufacturers are dominated in this kind of relationship, i.e. both of the suppliers (often core brokers and scrap yards) and the customers. This is because the demand for cores is greater than the supply. According to Cox [16], a buyer should only commit itself and trust a supplier if the buyer dominates that supplier. In this case, it is the other way around, and it can be hard for the remanufacturer to trust and commit to the suppliers. In a relationship that lacks both trust and commitment, it is hard to collaborate long-term and is better suited for the short-term. This is however contradicted by the fact that Company F is satisfied with working this way, and it can collaborate with its suppliers on the long-term, even though it is dominated.

Deposit-based relationship

The deposit-based relationship has been a traditional way to work for independent remanufacturers with some types of suppliers. An advantage of using this take-back system is that it is possible to balance supply and demand since the customer needs to return a similar product when purchasing a product, as stated by Östlin [7]. Östlin [7] also discusses how sometimes a core that is returned cannot be remanufactured, and therefore it is not always certain that there is a match between supply and demand, which has been verified by the companies in this study. It has been confirmed that companies that use this relationship often need complementary purchases from other suppliers in order to deliver remanufactured products to the customer. Another disadvantage with this relationship is that it will tie up a lot of capital in stock keeping, due to a core being returned when selling a product.

Close collaboration with the OEM

An advantage when collaborating with an OEM is that the remanufacturer can collect cores from cars with warranties. Company F stated that in its case, it is impossible to remanufacture components from cars with warranties since those end customers go to licensed repair shops, and since Company F does not collaborate with the OEM, these cores will never be available for them. Thus, if independent remanufacturers choose not to collaborate with an OEM, they will miss out on a potential market of cores, or radically increase their inventory costs by purchasing these cores and storing them until the demand for cores outside the warranty period grows sufficiently large enough to be able to sell the stored cores, making the remanufacturer subject to lead-time lag. Company F confirms that this is an issue in its business, and it sometimes stores cores awaiting the demand. A disadvantage for a remanufacturer when choosing to collaborate with an OEM is the risk of becoming too dependent. Company E has changed much of its business, and today is focused on remanufacturing diesel particulate filters. This could be a dangerous choice in the long-term, however, since it is not certain that cars will use diesel fuel in a number of years.

In Table 4, a summary of the advantages and disadvantages with relationships and collaboration with an OEM is compiled.

Importance of supply chain parameters

In a questionnaire sent out to the participating companies, they were asked to rank some parameters and the importance of these parameters for them, depending on what type of supplier it is. The parameters are *on-time delivery, purchasing price, geographical position* and *delivery performance* (ordered quantity corresponds to delivered quantity).

Figure 3 shows results from the general part of the survey. The result shows that the three most important parameters (for all kinds of suppliers) are the following:

- *On-time delivery*,
- *Purchasing price*, and
- *Ordered quantity matches delivered quantity.*

The *geographical position* was found to be not as important.

When comparing one parameter for the four different kinds of suppliers, it was shown that the *purchasing price* is more important when buying from a core broker than from any of the other three suppliers. An explanation for this is that a remanufacturer normally purchases from core brokers for complementary reasons, i.e. when there is not enough supply from the other kinds of suppliers.

The same parameters have been evaluated in the supplier-specific part of the quantitative survey, where specific individual relationships have been evaluated. Notable is that many companies have stated that they do not get the *ordered quantity*; in fact, in 66% of the investigated relationships, the remanufacturers do not get the correct quantity, something which they rank as very important. The parameter *on-time delivery* was not considered to be a problem for the evaluated supplier relationships. Furthermore,

Table 4 Advantages and disadvantages of relationships and collaboration with an OEM

Relation	Advantages	Disadvantages
Reman-contract	Dominating position	Risk of dependency
	Do not need to source cores	Sorting costs
	Access to more cores	
Buy-back	Flexible	Weak power position
	Good for complementary purchases	Hard to fully commit
Deposit-based	Balance supply and demand	Hard to get a steady flow
Close collaboration with an OEM	Access to more cores	Risk of dependency
	Possibility of lower inventory costs	

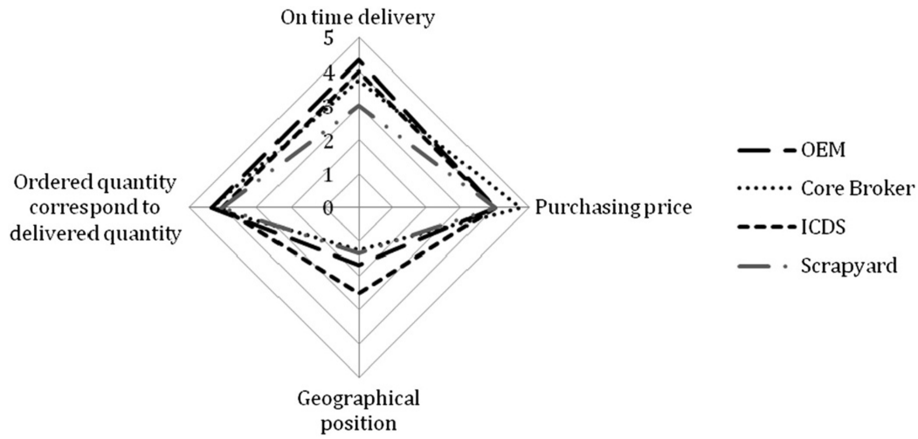


Figure 3 Importance of parameters between a remanufacturer and four different kinds of suppliers. 1 = not important and 5 = very important.

the *geographical position* was not considered to be an important parameter either, nor was it a problem for the participating companies.

On-time delivery

In the questionnaire that was sent to the participating remanufacturers, they were asked to rank how important it is for them to get their orders on time. The ranking ranges from 1 to 5, with 5 meaning very important. As seen in Figure 3, *on-time delivery* was shown to be an important parameter. The kind of supplier that stands out a bit is the scrap yard; *on-time delivery* for it is only ranked at 3. A reason for this is that purchases occur very infrequently from scrap yards; therefore, the need to get the order on time decreases. For the rest of the suppliers, *on-time delivery* is ranked close to 4, and is ranked highest for OEM/OES at 4.33.

On-time delivery is in general considered to be important; however, the remanufacturers do not consider *on-time delivery* to be a problem. The supplier-specific questionnaire showed that only one of nine suppliers (11%) normally has a problem with *on-time delivery*. In that case, the lead-time normally varies between 1 to 3 weeks. Since *on-time delivery* is not seen as a problematic parameter but *delivery performance* is seen as a very problematic parameter, it means that the suppliers of cores prefer to send a few cores on time rather than wait until they have the ordered amount. This is supported by the core broker interviewed in the CAN-REMAN project, who stated that they divide the 'good cores' so that each customer gets at least some good cores; they then fill out the order with cores of lesser quality. In this way, they are able to deliver cores to the remanufacturer on time and provide at least some cores with very good quality.

Delivery performance

Company E says that *delivery performance* in the business from all kinds of suppliers is generally poor, even from the OES. The other remanufacturers share the same opinion, as many do not receive the number of cores ordered. They state that the reason for the poor *delivery performance* is that the availability of cores is limited, with demand greater than supply. The remanufacturers were asked to rank the importance of the *delivery performance* of the supplier, i.e. that the ordered quantity corresponded to the delivered quantity. It was shown that this is a very important parameter for remanufacturers; for all four kinds of suppliers, it ranked as 4 or higher.

Delivery performance is, in general, poor in the remanufacturing of automotive components business. This is because there is not enough supply to cover the demand. Many of the interviewed remanufacturers say that the availability of cores is one of their biggest problems, and due to the shortage of cores, suppliers cannot deliver what they order. This opinion is shared by the core broker, who says that there are not enough cores in the market to satisfy demand. In the supplier-specific evaluation, it was shown that four of the six studied remanufacturers (66%) do not receive the quantity of cores ordered. In addition, at two out of five core suppliers (40%) where the ordered amount was not received, the amount varied by more than 50%. This shows that the remanufacturers have a problem with *delivery performance*.

Figure 3 shows that the remanufacturers rank the importance of *delivery performance* highly; the ranking is 4.33 out of 5 that the ordered amount corresponds to the delivered amount. *Delivery performance* plays a large role when choosing a supplier; if a supplier can deliver an amount that is close to or exactly the same as ordered, that supplier would be very lucrative. However, it has proven that there are no suppliers that can deliver the ordered amount, and even large suppliers such as OEMs cannot provide the exact amount. A reason for this is the lack of cores on the market; a reason for the lack of cores, in turn, is that the quality is unknown and may have to be scrapped by the remanufacturer. This means that in order to satisfy the demand for spare parts, components must be newly manufactured.

Another reason for the lack of cores is the lack of awareness of the value of the cores. Interviews with both remanufacturers and a core broker have shown that scrap yards do not see the value of a single core, and may for that reason mishandle the core and treat it incautiously, or just scrap the whole car instead of cannibalize it into components. It may not be profitable to cannibalize a single car to get a single core and sell it; therefore, scrap yards will not do it for one or many cars, not realizing that it could be profitable to cannibalize a great quantity of cars into components and sell them. This can be compared with what Ellegaard et al. [17] describe as transaction cost economics (TCE), which aims to maximize the total profit. If a TCE approach is implemented, it is meant to maximize the seller's total income in an exchange relationship. This will lead to a minimization of the total work while the revenue and profit are maximized. Every seller, OEM, ICDS and scrap yard needs to assess whether it is lucrative to disassemble parts and sell them to remanufacturers.

Today, there is little awareness among suppliers regarding the value of cores, something that remanufacturers need to increase. If each of the remanufacturers' suppliers does an assessment and comes to the conclusion that the total profit will increase when disassembling cars to get components, more cores will be available and the gap between supply and demand will decrease. A further advantage that remanufacturers will gain if the awareness of the value of cores is raised is that the handling of cores will be more careful. This could lead to the remanufacture of more cores. If assessments are executed and they show that the total profit will increase when cars are disassembled in order to get components, this will lead to a win-win situation where the profit will increase for the scrap yards and more cores will be available for the remanufacturers, so that they in turn can increase their profit.

Purchasing price

As seen in Figure 3, the *purchasing price* is regarded as very important for an independent remanufacturer when choosing supplier, with a ranking of 4. The independent remanufacturers rank this parameter even higher when buying from core brokers, with an average rank of 5. Company E does not consider the *purchase price* when obtaining cores from an OEM/OES since it never owns the cores and therefore does not need to buy them. For the other remanufacturers that do not work in this manner, the purchase price is still a very important parameter, as seen in Figure 3. Also of note is that the remanufacturers consider the *purchasing price* as even more important when buying from core brokers, where it is ranked at 4.75. A reason for this may be that many of the remanufacturers in the CAN-REMAN project procure from core brokers for complementary reasons; they try to satisfy demand by purchasing from suppliers that they normally do not use. These remanufacturers will choose the core broker that can offer the lowest prices. Therefore, this parameter will become even more important when buying from core brokers. This investigation has shown that some remanufacturers never actually purchase the cores; they are only performing a service for an OEM by remanufacturing products. To these remanufacturers, the purchasing price is not a problem and a parameter that they do not take into consideration; the interesting parameter will instead be the selling price for providing the service for remanufacturing one core.

Geographical position

The *geographical position* is ranked as not so important when choosing supplier, as seen earlier in Figure 3. For one kind of supplier, however, it was ranked somewhat more importantly: ICDS ranked at 2.5 compared to the others with an average of 1.4 out of 5. A reason for this is that the size of ICDS ranges from very large, such as e.g. large retailers of car parts, to very small organizations. It is unlikely that the independent remanufacturers would want to collaborate with a very small ICDS that provides few cores and that is situated very far away. In this case, the purchase price per unit will be higher since no economy of scale can be applied for the transport; in that case, the margin would disappear. It can be argued if the same reasoning could be applied to scrap yards and core brokers, which also could be small organizations, but in those cases, the suppliers often can supply several cores. The *geographical position* is not a very important parameter when choosing a core supplier. Since there is a shortage of cores and the remanufacturers normally can sell everything they remanufacture and they are doing everything in their power to procure cores. Therefore, they are not likely to take into consideration the *geographical position* when choosing a supplier.

Quality

An interesting aspect regarding quality of cores is that there are always a percentage of cores that is not possible to remanufacture. The remanufacturers in CAN-REMAN state that they normally cannot remanufacture 20% to 40% of the cores that they purchase, but they do not consider this to be a major problem. In many other businesses, it would be considered a significant problem if 20% to 40% of the products they purchased would be useless. Some of this can be explained by the nature of the remanufacturing business, where remanufacturers take back cores and the quality is unknown. However, it is debatable whether suppliers to the remanufacturers effectively sort out the bad cores from the good. For the supplier, sorting is a resource-intensive activity due to the excessive time and cost involved; therefore, they would want to leave that activity with the remanufacturer. The remanufacturer would not want to do the sorting itself since, as stated earlier, it is an extra cost. However, the demand is much greater than the supply and it can be hard for the remanufacturer to request that the cores arrive sorted. Therefore, the remanufacturer must surrender to the suppliers' wishes, and therefore, there are no incentives for the supplier to sort out bad cores before supplying the remanufacturers. A further positive aspect for the supplier to send the cores unsorted is that it is possible that the remanufacturer lets a bad core 'go through' the sorting process, and the supplier will therefore get paid for a useless core. The suppliers to the remanufacturers are thus in a favourable situation, where they can avoid the sorting cost and also earn more money by selling bad cores.

Conclusions

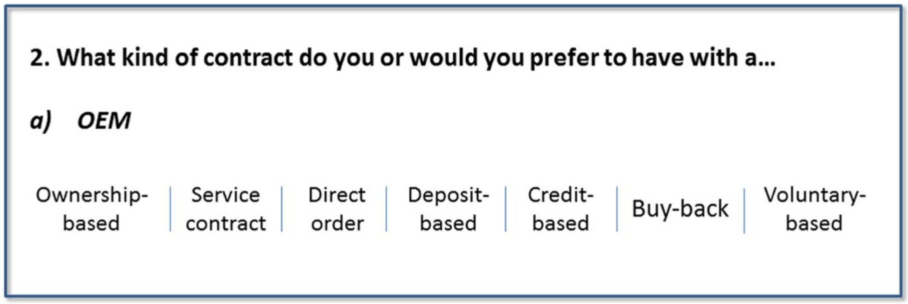
This paper has identified the most common relationships that independent remanufacturers of automotive components in Europe have with four different kinds of suppliers. While most of the identified relationships have already been described by Östlin et al. [12], one new relationship was found: the *reman-contract* relationship where the OEM owns the core and the remanufacturer just performs remanufacturing including some sorting and storing.

This paper has also ranked parameters considered to be important in a relationship between remanufacturers and their suppliers. The most problematic parameter is to get the ordered quantity to correspond to the delivered quantity, i.e. the *delivery performance*. This was ranked to be the most important parameter in a relationship with a supplier of cores, but in 66% of the cases, the remanufacturers do not receive the quantity that was ordered, and the delivered quantity varied widely. This is mainly due to the lack of cores and knowledge about the core values.

In order to verify and specify the attributes of the *reman-contract* relationship, further investigations and discussions with contracted remanufacturers and OEMs should be conducted. Since using the *reman-contract* relationship with suppliers seems to be a very lucrative strategy for remanufacturers, especially if the remanufacturing process is unique, this would be a very interesting area to continue investigating. It can be argued whether it is sufficient to investigate just six remanufacturers, as in the CAN-REMAN project. It would be an interesting future investigation to include more remanufacturers to verify the result from this paper. In addition, other types of remanufacturers e.g. OEM and contracted remanufacturers' situations would be interesting to explore. This research has been focusing on the European automotive remanufacturing market. It would be interesting to also study other industry sectors and parts of the world where other core suppliers could be available, e.g. insurance companies.

Methods

In this investigation, there were four sources of data and theory collection: 1. Literature study; 2. Questionnaire designed by the authors; 3. Interviews conducted by the authors; 4. Previous interviews made in the CAN-REMAN project.


2. What kind of contract do you or would you prefer to have with a...

a) OEM

Ownership-based	Service contract	Direct order	Deposit-based	Credit-based	Buy-back	Voluntary-based

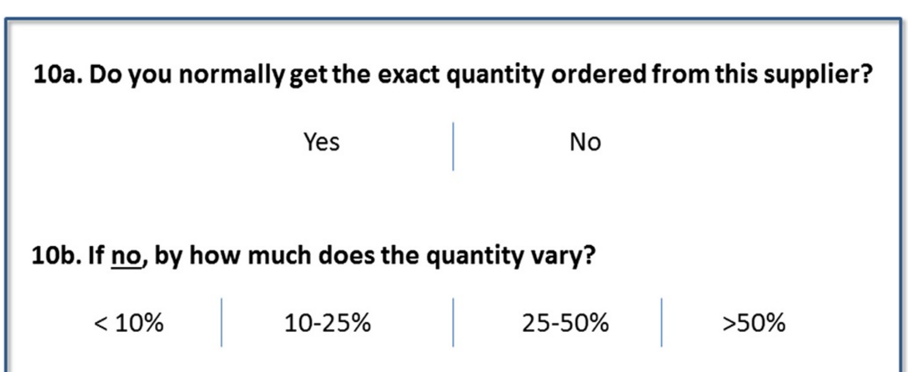
Figure 4 Snapshot of the questionnaire (general part).

The questionnaire was designed and distributed to the participating companies, and was answered by a person on a managerial level with a good overview of the company's suppliers. The questionnaire was divided into two parts: a general part (Figure 4) and a supplier-specific part (Figure 5). In the general part, the receiver was asked to rank the following parameters:

- On-time delivery
- Purchasing price
- Geographical position
- Ordered quantity corresponding to delivered quantity

The ranking of the parameters is from 1 (not important) to 5 (very important). The parameters were ranked for each type of supplier described earlier. The supplier-specific part was formed to investigate and evaluate certain specific supplier relationships.

The authors also conducted interviews with some of the companies, either by visits in person, telephone or e-mail. These interviews were conducted in order to get a general overview of the business and to identify interesting patterns between the remanufacturers and their suppliers.


10a. Do you normally get the exact quantity ordered from this supplier?

Yes	No

10b. If no, by how much does the quantity vary?

< 10%	10-25%	25-50%	>50%

Figure 5 Snapshot of the questionnaire (supplier-specific part).

Abbreviations

CAN: controller area network; ELV: end-of-life vehicle; ICDS: independent car dealership; TCE: transaction cost economics; OEM: original equipment manufacturer; OES: original equipment service; SME: small- and medium-sized enterprises.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors have collaborated in writing on the manuscripts of this paper. ES supervised and planned the M.Sc. project. SL and DO planned and performed the survey and interviews within their M.Sc. project, which was the basis for this paper. SL and DO summarized the survey and interviews and wrote the first draft of the manuscript. A previous version of this paper was presented by SL and DO at the 1st International Conference on Remanufacturing in Glasgow last summer. All authors read and approved the final manuscript.

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