Sitcharangsie, Sakraan and Ijomah, Winifred and Wong, T.C. (2017) An investigation of the value recovery process in the automotive remanufacturing industry : an empirical approach. In: 3rd International Conference on Remanufacturing, 2017-10-24 - 2017-10-26, Linköping University. ,

This version is available at https://strathprints.strath.ac.uk/62436/

An investigation of the value recovery process in the automotive remanufacturing industry: An empirical approach

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Abstract

Remanufacturers have been experiencing challenges when optimising the value recovery process mostly due to the uncertainties of cores regarding quality, quantity, arrival time and demand. Hence, the aim of this study is to gather relevant information from the literature and current industrial practice and then define research gaps to improve the decision-making practice for managing value recovery processes in the automotive remanufacturing industry. The case studies used in this paper are an original equipment remanufacturer and a contract remanufacturer. Both companies in the case studies use credit-based systems to take back old cores which can reduce the severity of cores' unavailability. The ability to access the parts and specifications of the original equipment was the primary factor considered by the contract remanufacturer before deciding to remanufacture the product. In daily operations, the condition of cores was the main factors the OER and the contract remanufacturer considered to make a decision. Finally, the results of this study indicate further research areas from the intersection of industry's needs and research gaps.

Introduction

There has been an increasing amount of economic and environmental issues which have challenged the manufacturers to manage end-of-life products more efficiently by recovery processes to extend the life of products. Remanufacturing brings used products (cores) to at least the original equipment manufacturer's (OEM's) performance specification and warranty by full disassembling, restoration and replacement of its component, while repairing is only the modification of specific faults of products which is covered by its warranty only for the parts which have been replaced [1]. Remanufacturing is the most efficient method among other recovery operations because it can maximise material usage, reduce production cost and increase waste recovery. Although remanufacturing is an efficient process, not all goods can be remanufactured. Remanufacturable products should have these characteristics: non-consumable products, easy to find available components at a reasonable price, slow product obsolescence [2]. Undoubtedly, the automobile industry is the most dominant target of remanufacturing in the world, accounting for two-thirds of remanufacturing business [3]. The conventional remanufacturing process includes disassembly, cleaning, inspection and sorting,

reprocessing, reassembly and testing [2]. However, remanufacturers face challenges in their production planning and control which can be categorised into these characteristics by Guide, 2000 [4]:

1. The uncertainty considering timing and number of returned products
2. The ability to balance returned products with demands
3. The disassembly of returned products
4. The uncertain recovery rate of return products
5. The need of reverse logistics
6. The difficulty of material matching
7. The uncertainty of material's routeings
8. The uncertainty of processing times

Therefore, the aim of the research is to explore and discuss characteristics, challenges and current practices of the automotive remanufacturing industry. This can be achieved by reviewing relevant research papers and by investigating current industrial practices, as well as by defining key aspects for further study about the decision-making process in the automotive remanufacturing industry.

Literature Review

The relevant academic literature provides a very useful background for understanding the business operations prevalent in the automotive remanufacturing industry to find suitable techniques for optimising returned products. Ostlin et al. concluded that strategies to manage cores in terms of timing and return rate depended on stakeholder relationships [5, 6]. It was stated that a buyback relationship is frequently found in the automotive remanufacturing industry [6]. In buy-back relationships, the remanufacturers buy cores from core dealers or scrap yards [6]. It can fulfil the product demands of independent remanufacturers while their challenge is to find rare cores to meet the requests of the buy-back system. A credit-based relationship is also common in the auto parts' remanufacturing industry. After clients bring their used products to remanufacturers, they will get credits as a discount to purchase a remanufactured product. Unlike a buy-back system, a credit-based system requires considering quality before giving credits. Also, a credit-based method can help remanufacturers to balance the supply and demand. However, this system is complex and is challenged by the price uncertainty which influences the customers to choose not to return used products.

In operational decision making, there were many factors to consider in the managing of the returned products. The required information for the adoption of the End of Life (EOL) strategy were time [7], properties [8] and cost[7, 8]. To match demand and supply in the remanufacturing industry, the expected product lifespan, the technology change rate and the component's breakdown rate were the main factors that affected the arrival and demand for remanufactured products [5]. Remanufacturers require to understand the lifecycle of products because the number of available products may change depending on various production times [5]. Moreover, the components can become outdated when manufacturers develop new models of products [9]. Not only quantities per time but also core quality were mentioned in many previous studies. Suitable criteria to predict a core's quality were product usage time and failure conditions [10], as well as remanufacturing expenses [11, 12], and remanufacturing time [13]. Yang et al. discussed the cores' quality in terms of the remanufacturing cost [14]. This cost comprised the cost of disassembly, cleaning, testing, remanufacturing, and repacking [14].

It appears that most studies about the core acquisition policy were conducted to maximise the economic profit under uncertainty of cores' quality [11, 12, 14-18]. However, there were some papers which mentioned a policy of balancing out the

economic and environmental aspects by including carbon tax in the budget [14]. The majority of existing papers are restricted to a quantitative method of optimising the amount of acquired cores under a single period of acquisition. However, Yang et al. has demonstrated a model for multiple acquisition periods because it was more practical in an industry where some remaining cores were kept to meet future demands [14].

The automotive industry needs solutions for all of the challenges stated by Guide (2000) except the difficulty in material matching [19]. It was reviewed that from 2000-2009 there was a lack of studies about production planning and control in remanufacturing regarding specific remanufacturing challenges [20] as shown in table 1. It was shown that ordering systems associated with the difficulty of material matching was a research gap [20]. However, the authors of the current study have discovered additional evidence that some researchers had already fulfilled the gap by conducting studies in this area. Kontaras et al. (2010) and Su and Lin (2015) studies came out about the purchasing order of new products and remanufactured products in the remanufacturing industry [21, 22]. Kontaras et al. (2010) compared two operational policies: one about several batches of used products with a single batch of new products or one about a single batch of used products with several batches of new products [22]. Su and Lin (2015) prepared a mathematical model of the ordering system under the situation of uncertainty with various types of components, component sources and machines [21]. Additionally, Bazan et al. (2016) pointed out that there were more than enough papers about inventory management and control which takes into account the economic perspectives [23]. Therefore, environmental aspects are under-researched and, therefore, suggested for further studies [23]. In conclusion, the summary shown in table 1 provides the identified study gaps by the analysed authors.
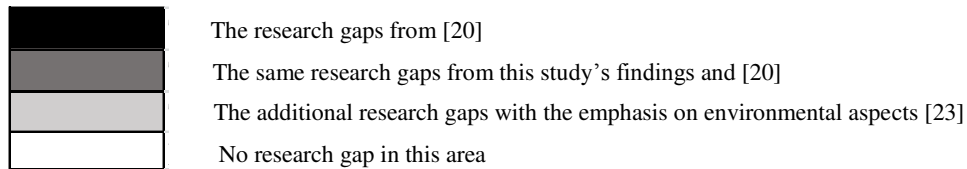
Methods

This research was conducted by employing the literature review of previous studies and two case studies, which were carried out by the authors of this paper. Previous authors undertook the theoretical studies. However, the case studies were selected for this paper because data from empirical research can answer questions and develop and test ideas based on direct experience and practical observations [24]. This method is suitable because the recovery process in the automotive remanufacturing industry is case-dependent and affected by various factors.

The first case study is about an original equipment remanufacturer which offers engine remanufacturing, and the other case study is about a contract remanufacturer which offers remanufactured fuel injection systems and repairing services. The primary source of information is based on structured interviews. Before the interviews, the authors reviewed the previous studies about decision-making in the remanufacturing industry to create questionnaires for the interviews. The participants in the discussion are: a core management manager, a production manager, and a director. Direct observations were also used during the visit to the company. Moreover, additional data including photographs, documents from the companies and data from the internet were also collected.

Table 1. The research gaps identified in literature review on production planning and control regarding challenges in remanufacturing

Source	Challenges	The activities of production planning and control in remanufacturing system					
		Forecasting	Aggregate planning	Master production scheduling	Ordering systems	Capacity planning	Inventory Management and Control
[20]	1. The uncertainty considering timing and number of returned						
The current study							(light gray)
[20]	2. The ability to balance returned products with demands						
The current study							(light gray)
[20]	3. The disassembly of returned products	(black)	(black)				
The current study		(dark gray)	(dark gray)				
[20]	4. The uncertain recovery rate of return products						
The current study							(light gray)
[20]	5. The need of reverse logistics						
The current study							(light gray)
[20]	6. The difficulty of material matching	(black)	(black)	(black)	(black)	(black)	
The current study		(dark gray)	(dark gray)	(dark gray)		(dark gray)	(light gray)
[20]	7. The uncertainty of material's routeings	(black)	(black)	(black)			(black)
The current study		(dark gray)	(dark gray)	(dark gray)			(dark gray)
[20]	8. The uncertainty of processing times						
The current study							(light gray)

(black)	The research gaps from [20]
(dark gray)	The same research gaps from this study's findings and [20]
(light gray)	The additional research gaps with the emphasis on environmental aspects [23]
(white)	No research gap in this area

Results and Discussion

Case study A

Company A is an engine OEM remanufacturer. They operate their business by separating remanufacturing and manufacturing lines. 95% of their activities are remanufacturing while the rest is producing new automotive parts for spares.

Challenges of case study A

The primary difficulty is the availability of parts. Company A provides various models of automotive parts. It may be hard or expensive to source the right parts at the right time because those automotive parts might be obsolete or produced in small volumes. Moreover, not all customers return cores back to the remanufacturer. One core might give 50-90% of usable parts. However, the remanufacturer does not know the quantities and types of new parts until they strip the cores.

When the engines arrive, the operators disassemble products into smaller parts. Therefore, the challenge is related to the combination of materials because the remanufacturer has to manage both the remanufactured parts and new parts to replace faulty products. Moreover, the remanufacturer has to deal with oversized parts and undersized parts. For example, a shaft will be remanufactured to be an undersized part and has to compensate with oversized parts fitting. In summary, some parts are new, while others are remanufactured or need a change in dimensions for the remanufacturing of one engine.

Case study B

Company B is a contract remanufacturer which provides remanufactured fuel injection systems. 95% of their activities are remanufacturing while the rest is repairing. Most of their repairing services are for B2B customers (95%).

Challenges of case study B

The main challenge is the availability of parts. Company B provides various models of products to match the variation of models, thus responding to the demand of vehicle breakdown. Sometimes the customers order rare items, especially newly launched products. Also, company B needs to find the right cores from credible sources which can prove the characteristics and quality of the product provided. The uncertain quality of the core is also an important factor for remanufacturer B to account for in their planning, although it will only be a major issue if they have a low-quality batch of returned products.

According to the interview, the needs identified by the case studies are summarised in table 2.

Table 2. The needs to solve the problems from the case studies

The problem	Detail of the problem
Availability of parts	1. The uncertainty considering timing and number of returned products 2. The ability to balance returned products with demands
Managing multiple components	1. The uncertain recovery rate of return products 2. The difficulty of material matching 3. The uncertainty of material's routeings

Recovery process of remanufacturing companies

When a customer's machine breaks down, the customer will order remanufactured products from the remanufacturer. The companies add a surcharge when they sell remanufactured products to customers to convince them to return the exact old model of cores to the remanufacturer within 12 months. Then, clients will get credit to discount their surcharge in their account. Giving credits to customers depends on the completeness of the cores. Company A does not know the exact percentage of their cores that have not been returned to their plant. However, their distribution centre, which is located in a different area, is responsible for tracking the return of cores. The reason why customers do not return cores back to remanufacturers may be because the customers think it is worth keeping cores as spare parts. On the other hand, company B knows that they had to buy 22% of total cores from core dealers due to missing cores in the loop of the supply chain.

Company A's customer is their distribution warehouse which focuses on the European market. Then the distribution centre will sell products to end customers, retail customers and local franchises. In contrast, customers of company B are garages and the OEMs. The components' suppliers of company A are other subcontractors and its parent company. However, core dealers are responsible for sourcing cores from scrap yards for company B. Company B's strategy is to acquire cores classed as A-quality before beginning the process so if company B finds some defects from the core dealers, they can return those batches of cores immediately, and company B will get credits from dealers for future purchases.

After the companies acquire cores, they have an initial inspection for viable cores during the pre-sorting process to save disassembling time because they can neglect unwanted parts immediately from visual inspection without full disassembly. However, the process of disassembling is important to find the remanufacturable parts among the sub-parts. Companies A and B have different strategies they use to hold items. If the remanufacturer B finds those cores are not worthy of being remanufactured, they will keep them for three months. Unless the customers want them back, company B will sell scraps to local recyclers. After the inspection process, companies A and B remanufacture products to the OEM's standards using the OEM's parts and the OEM's test equipment/data. Core acquisition within the remanufacturing industry is a multiple-period operation since remaining cores are often utilised in the next batch. The flow charts of core acquisition for company A and company B are shown in figure 1 and figure 2 respectively.
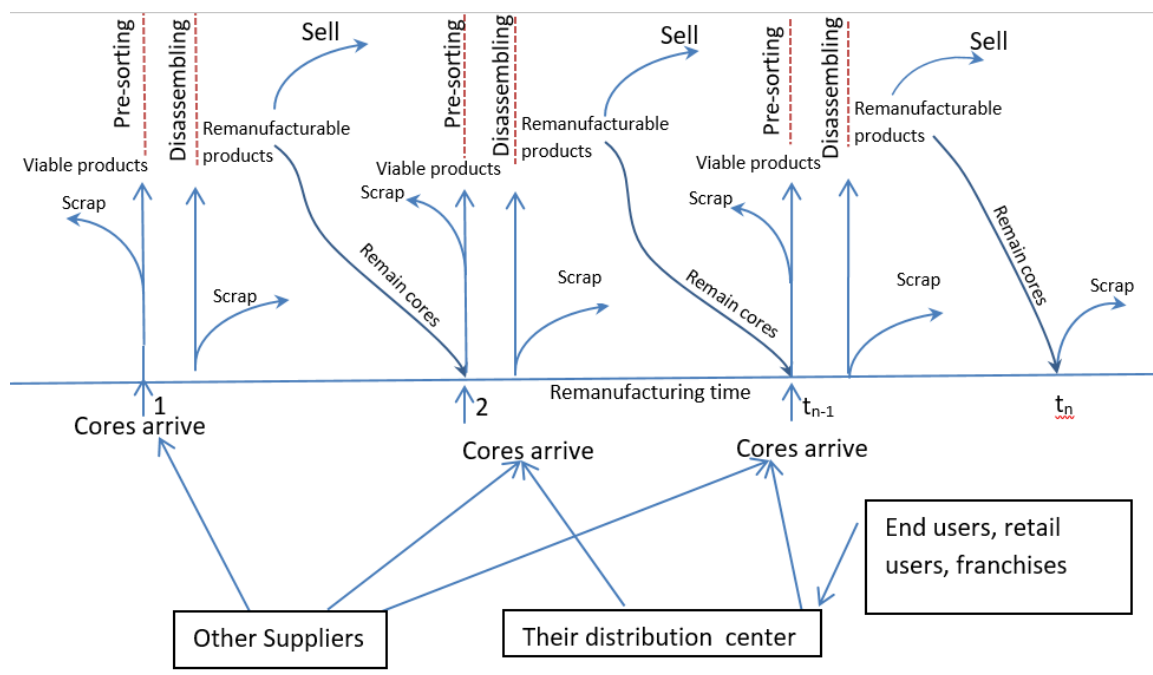

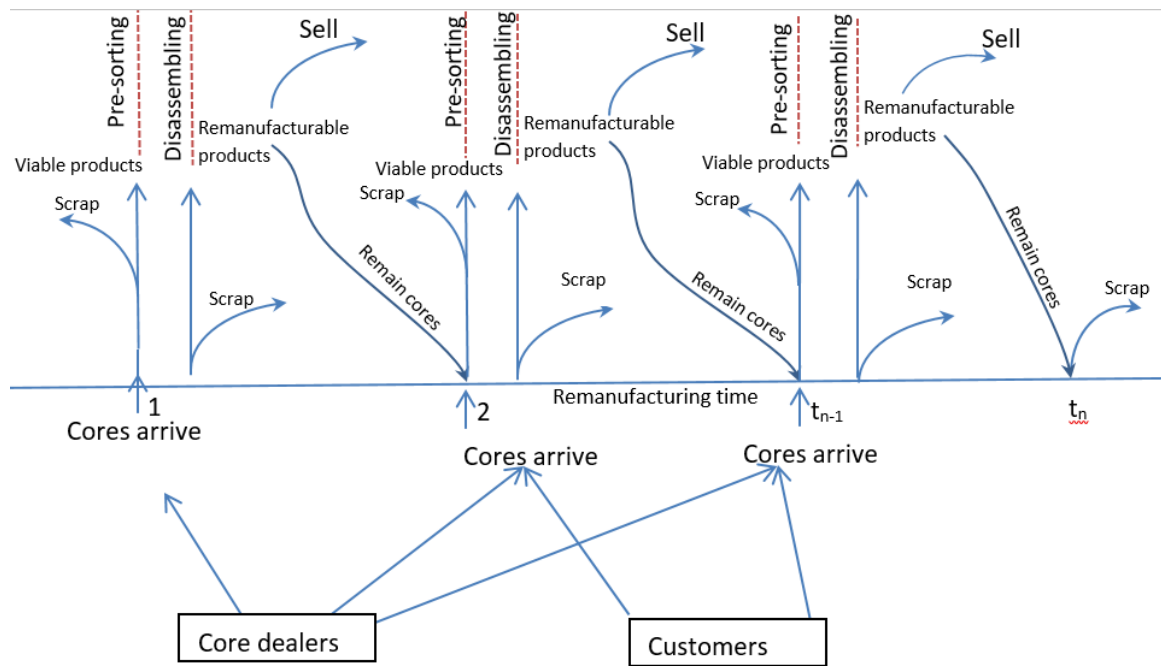Figure 1. The flow chart of Company A (OER)'s core acquisition

Figure 2. The flow chart of Company B (Contract Remanufacturer)'s core acquisition

The warranty of new products covers one physical life of that product. Therefore, the best business opportunity for remanufacturers is after the warranty of new products finishes because of suitable demand and core availability. The need of genuine remanufactured products increases after the warranty period finishes since products are starting to get worn out and customers return old products to remanufacturers. However, companies A and B try to find remanufactured products for their customers whenever those products are introduced in the market. The business consideration of companies A and B are shown in table 3.

Table 3. The business consideration of companies A and B

	Company A	Company B
The physical life of products	Five years or more	Three years or more
The time length they allow customers to return old cores after purchasing their remanufactured product	One year	One year
When they start to remanufacture products	Whenever after launching of brand new product	Whenever after launching of brand new product
The right time to remanufacture	After five years of offering brand new products	After three years of offering brand new products
The time period between remanufacturing cycles	Ten years from year 5	From year 2 to year 15
The maximum time allowance of remanufactured products in their inventory	Two years	Two years

In term of inventory management, both company A and company B produce remanufactured products at the production rate recommended by their monitoring systems. The distribution centre of company A is responsible for tracking the number of new and remanufactured products and informing company A to remanufacture a certain number of products. In contrast, company B can monitor their inventory via their on-site monitoring system which is based on previous sales data.

Operational strategy

There were three objectives for the companies to operate their businesses:

1. Assembling a certain number of remanufactured parts.

This objective was the most important one for company A and company B. They set the target of a certain number of remanufactured parts they produce per day. The amount of production is based on the sales information they have.

2. Making a return on their investments in cores.

Both of the companies A and B use the credit-based system to manage their cores. When they sell cores, they add a surcharge to the bill. They increase the incentive for the customers to return the same old unit back to the system by giving customers credits to discount this surcharge. It helps them to continue their business in the future.

3. Neglecting unnecessary jobs/tasks

Companies A and B will not wait until the required parts are returned if they have a limited operational time. They will buy new parts if it is necessary and profitable. Moreover, company B tries to buy the right cores eg. specific number of parts, core grade At first, Company B can minimise time and labour to strip, clean, reprocess or scrap a purchased core. However, company A cannot avoid the complexities of the sorting process since engines' bill of materials contain more information about various types of components. As a result, company A has to accept multiple cores with many varying levels of conditions since they do not know the condition until the full disassembly process is completed. Company A carries out welding if they can fix the cores' condition while company B does not rework products.

Factors influencing the decision-making process

When considering all criteria in the decision-making process in general, a comparison of each factor's relative importance (as a percentage) is shown in figure 3. The condition of products was a major factor in the daily operation of the remanufacturing process for company A and company B.

Company A thought that the condition of cores was the most important factor for them to decide in the recovery process. They thought both the internal and external conditions of cores were equally important because they investigated cracks, wear, and damage to decide on whether to reuse or remanufacture those parts. Projected price and cost were the next most important factors. Company A considered these factors to evaluate the profitability of remanufacturing parts. For example, it is worth to remanufacture them today because of the wider availability and lower price of parts. The part's age, complexity of components, fasteners/parts availability, and historical price and cost were the latter of factors rated as equally important. Company A takes the part's age into account since this factor could affect the decision-making if some parts are obsolete. They considered historical prices and cost because they usually compare current price/cost with historical price/cost when they purchase or sell products. When parts are older, the

demand and the volume is lower, so the cost of ordering certain types of parts tends to increase. Another factor they considered was the availability of parts and fasteners. Occasionally, they can buy only a complete assembly of parts from their parent company. The individual parts are difficult to find because they come from sub-suppliers. Although, smaller parts are cheap per unit, so the suppliers allow the remanufacturer A to buy a high volume of products. Therefore, this factor influences company A to purchase the complete assembly parts rather than to buy smaller parts if they need only a small number of sub-parts. Company A also took the complexity of components into consideration to find out how to remanufacture complex products.
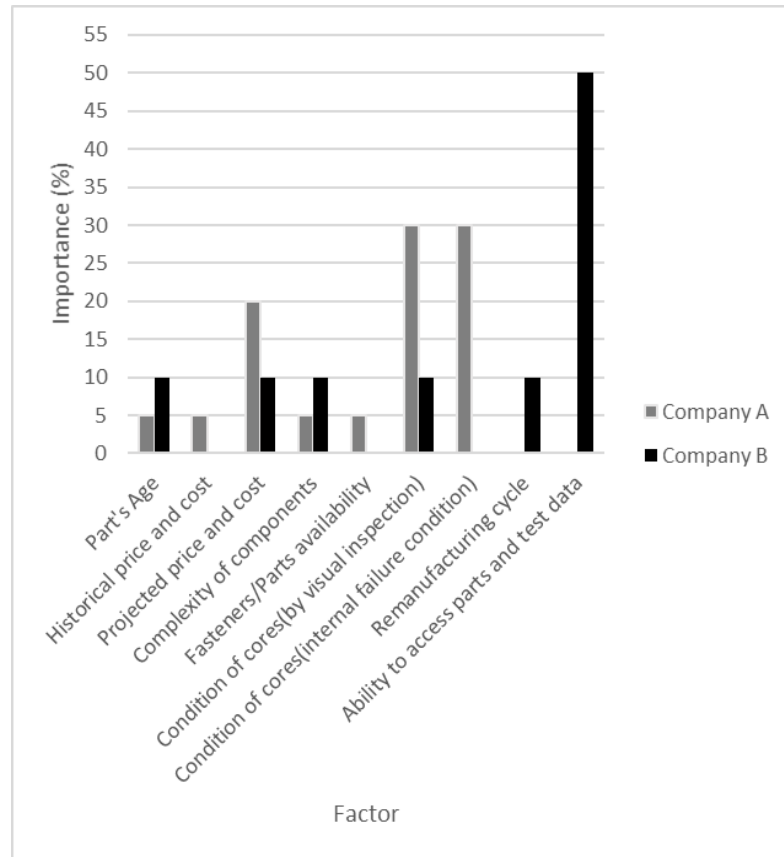

Figure 3. The comparison of each factor's relative importance

The ability to access the parts and specifications of the original equipment (O.E.) was the primary factor taken into account by company B before deciding to remanufacture the product. Interestingly, this factor was important for a contract remanufacturer but was not the primary focus for the OER which has a greater ability to access the product information and material. Company B also considered other factors including the part's age, projected price and cost, remanufacturing cycle, the complexity of components and condition of cores (failure condition investigated by visual inspection) which were rated as equally important. Company B considers the part's age when it introduces a new remanufactured product to the market. Normally the life of new products is three years, so the contract remanufacturer does not have many options during the first three years of a product's lifecycle since they are covered by the warranty of the manufacturer. Company B considers projected price and cost when they remanufacture parts and sell them at a competitive price compared to new products from the dealer. Remanufacturing cycle was

also a vital factor since company B could track products' remanufacturing cycle to predict when cores will be returned and see the ability of repeat business. They also considered the complexity of components since the testing machines may not be able to investigate all elements of new products. This can cause company B to invest in a new test bench.

The decision-making process

According to interviews, there are two phases of decision-making: the introduction of remanufactured products and decision-making in daily operations.

For introducing new remanufactured products to the market successfully, company A considers how to remanufacture products and checks available parts to introduce new remanufactured products by finding reasonable procedures, while company B mainly decides on remanufacturability by reviewing the ability to access the parts and specifications of the original equipment manufacturer

In their daily operations, the remanufacturers have a strategy to manage old cores by two methods: rejecting and accepting old cores.

In terms of criteria in discarding old cores, the type of damage was the primary factor for both company A and company B as shown in figure 4. If the damage is serious or the affected automotive parts are expensive, the remanufacturer will reject the parts immediately. However, the acceptance criteria according to company A and company B are different and described in the next paragraph. Obsolescence was only important for company A, while it was not a primary concern for company B. The reason for this is that company B's strategy allows them to acquire only specific part numbers. Customers are allowed to return only the same model they purchased from company B, while company A has a more relaxed strategy to allow the customers to return various models of cores. If company A found out that those collected parts can cause the failure, they would record the data in their system and reject those obsolete parts in the next round of remanufacturing to make sure they can guarantee their warranty.

In terms of criteria of acceptance of the old cores, company B is more selective than company A because the company B will take only intact parts with minor faults, whereas company A accepts various grades of cores: a full and undamaged engine, an undamaged engine with missing parts, and a damaged engine with both incompletions and faults. Company A gives a refund depending on part's completeness and faults. The evaluation of old cores is a step-by-step investigation. If it does not meet some criteria, the core's value is reduced. For example, in relation to a turbocharger, they will check how well it rotates and how many parts are missing before giving their customer credits.

Table 4 shows the comparison of each factor's relative importance (as a percentage) in their current practice to reject old parts. The remanufacturers have two options including fixing it or scrapping it. The scrap will be recycled by external companies. Undersized/oversized parts, weakened parts and overstocked ones are not failures according to company B; They do not weld or perform any related mechanical process on parts, so they have little possibility to weaken parts. They acquire only specific models of parts and they guarantee they can sell all the products on the shelf, so they have no problem of overstock. Also, remanufactured products from company B do not require the compensation of fitting, so they do not worry about undersized/oversized parts at all.
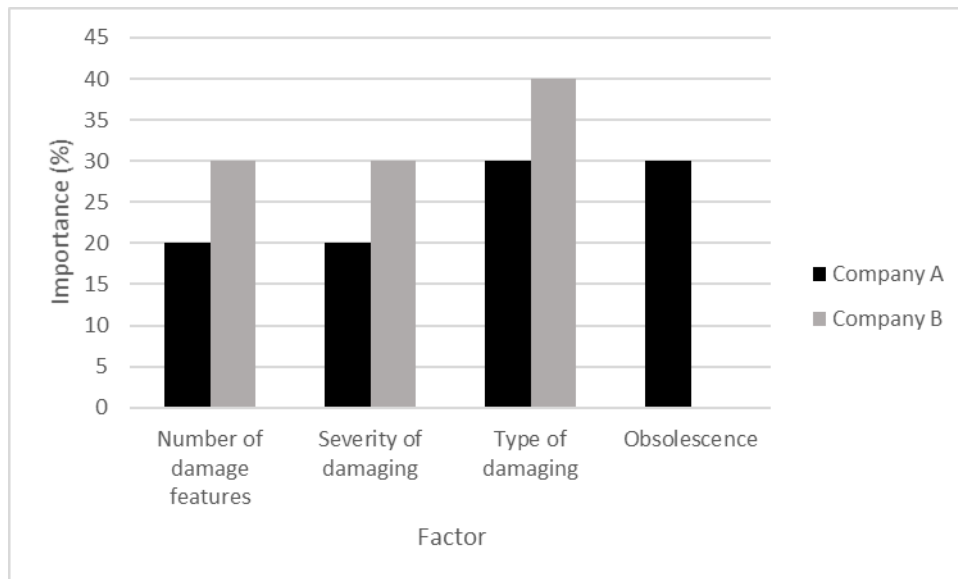
Figure 4. The comparison of factors' relative importance in rejecting parts for remanufacturing

Table 4. The current practice of the company of managing old cores with different conditions

The failure	Company A (OER who offer remanufactured engine)	Company B (Contract remanufacturer who provide fuel injection system)
Body damage	Unless the significant damage happens with expensive parts, they will try to fix it first.	Scrap it
Mating part lost	Fix it	Scrap it
Mixing with non-genuine parts or other models	Fix it	Scrap it
Obsolete	Scrap it	Scrap it
Cosmetic flaw	Scrap it	Scrap it
Material loss	Scrap it	Scrap it
Undersized/oversized parts	Scrap it	N/A
Weaken parts	Scrap it	N/A
Overstock	Scrap it	N/A

A comparison between the results of the empirical study and literature review

1. The current study and the previous research from [19] are about the automotive remanufacturing industry. However, there are some key differences between the current study and the previous study such as the percentages of remanufacturing activities, the type of operation systems and the remanufacturing challenges as shown in table 5. The symbol '✓' indicates remanufacturing challenges found in the remanufacturing system. Case studies from the current study are more relevant to the remanufacturing industry since there is a higher percentage of remanufacturing activities in the companies than that of [19].

2. Both previous studies and current practices from the industry demonstrated that the credit-based operational system was important for the remanufacturing industry. It can increase the incentive for customers to return used products back to the recovery process. Also, the credit system can help remanufacturers to predict and control their volume of returned products. If remanufacturers know the rate of returned products, they can estimate the number of products they should buy from suppliers to match supply and demand.

3. Both previous studies and current practice from the industry revealed that factors used to decide in the remanufacturing process related to the condition of used products, operational time and operational cost. The results from the case studies introduced a new factor, previously uninspected in the past studies. The ability to access the parts and specifications of the original equipment (O.E.) was the primary factor considered by the contract remanufacturer before deciding to remanufacture the product. The original equipment remanufacturer (OER) did not consider this factor because they can access all of the product information and material.

Table 5. The comparison between the previous study and the current study

	The previous study [19]	The current study
Participants	Automotive OEMs	Automotive OER and automotive contract remanufacturer
Remanufacturing activities in the company	10-40%	95%
Hybrid/Non-hybrid system	3 out of 4 companies performed in hybrid system	Non-hybrid system
Challenges		
The uncertainty considering timing and number of returned products	✓	✓
The ability to balance returned products with demands	✓	✓
The disassembly of returned products	✓	
The uncertain recovery rate of return products	✓	✓
The need for reverse logistics	✓	
The difficulty of material matching		✓
The uncertainty of material's routeings	✓	✓
The uncertainty of processing times	✓	

4. According to the case studies and previous studies, the remanufacturers should operate their business by analysing the lifecycle of products. The case studies uncover the details of operation considered in the products' lifecycle. Their business consideration included the physical life of goods, the time allowed for customers to return products, when to start to remanufacture products, the right time to remanufacture products, the time period between remanufacturing cycles, and the maximum time to keep products in the inventory.

5. Both previous studies and current practices focus mainly on economic aspects and quality of goods in making a decision in the remanufacturing industry. Environmental factors were not considered directly in the industry. Also, there is a lack of research

papers which reviewed multiple objectives: economic outcomes, quality of products and environmental aspects to optimise the remanufacturing process. Therefore, there are some research opportunities to conduct a holistic research about optimising the remanufacturing process by considering multiple objectives. It could be beneficial for both academic and industrial entities.

According to the literature review, the optimisation of returned products in the remanufacturing industry tends to be achieved by using mathematical modelling. It appears that most of the input data were hypothetical and theoretical, since the real data are incomplete or missing. While single-period modelling seems to be dominant in existing research papers, multiple-period modelling is required for further study since it is more practical than the single-period model in the industry as companies allow having products left in the inventory for future purchases.

There are numerous papers on production planning and control in remanufacturing. However, there is a need to bridge the gap between academic research and the requirements of the industry. The symbol '✓' indicates the intersection between the academic gaps and industry needs from our case studies as shown in table 6. It shows that production planning and control (PPC) activities to solve the challenges of material matching and uncertainty of material's routeings are areas for future research.

Table 6. The intersection between the academic gaps and industry needs from case studies

Remanufacturing Challenges	Production planning and control(PPC) activities				
	Forecasting	Aggregate planning	Master production scheduling	Capacity planning	Inventory Management and Control
The difficulty of material matching	✓	✓	✓	✓	
The uncertainty of material's routeings	✓	✓	✓		✓

Conclusions

The objectives of this study are to identify characteristics of the automotive remanufacturing industry, address the challenges and understand the decision-making process in the automotive remanufacturing industry. The contribution of this paper is the research into two case studies, which are two different types of remanufacturers providing different remanufactured products. Also, this study compares the industry's needs and the findings in the existing literature to bridge the research gap, and to offer insights for further research. The main conclusions are as follows:

1. The empirical approach can reveal the current practices in the automotive remanufacturing industry. Both case studies use the credit-based systems to take back old cores, as well as to plan and control the number of old cores to minimise cores' unavailability. It is necessary to fully inspect the condition of cores before deciding on their remanufacturability.

2. The ability to access the parts and specifications of the original equipment (O.E.)

was the main factor for the contract remanufacturer before deciding to remanufacture the product. However, this factor was not prioritised by the OER since they have more capability to access the specification information and material.

3. The condition of cores was the main factor considered in the daily operations of the OER and the contract remanufacturer. The policies of two remanufacturers to reject or accept old cores are different and depend on the type of product.

4. There is a lack of studies and current practices which employ multiple objectives, such as economic, technological and environmental perspectives, to decide on managing returned products in the remanufacturing industry

5. It seems that the most of the existing research papers about optimising returned products in the remanufacturing industry are restricted to the use of hypothetical or theoretical data as inputs in mathematical models since some data are missing or incomplete in the reality.

6. Aggregate production planning to solve material matching and uncertainty in material's routeings are interesting research areas that the author of this study will include in the next step of the project. The author assumes that the long-term planning could be better than short-time decision making to mitigate the effects of uncertainties in remanufacturing.

Authors' contributions

This study has offered two key contributions to the existing knowledge about the automotive remanufacturing industry. It appears that the nature of the remanufacturing industry is somewhat similar and somewhat different from the results of previous studies. These have been identified in the areas of characteristics, challenges, processes, and the decision-making of the remanufacturers. Also, this study recommends the appropriate methodology to close the gaps between theoretical research and practical implications of a decision-making framework for the automotive remanufacturers.

These contributions are beneficial for practitioners because it could help generate ideas to improve their existing decision-making in their industry. Also, researchers can use these contributions as a starting point for further research about the automotive remanufacturing industry.

Acknowledgements

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What I have considered each review comment

Reviewer A:

Minor review comments:

1. There are numerous grammatical errors in the paper, especially the wrongful use of the definite article 'the'. For instance, the company A,the company B.
   - I changed the text especially articles 'the' and few places where the word order was not right.
   2. Table 1: the representation of the Table 1 is ambiguous, more explanation is required to clarify its 'construct'.
   - I described that 'It was reviewed that from 2000-2009 there was a lack of studies about production planning and control in remanufacturing regarding specific remanufacturing challenges [20] as shown in table 1. It was shown that ordering systems associated with the difficulty of material matching was a research gap [20]. However, the authors of the current study have discovered additional evidence that some researchers had already fulfilled the gap by conducting studies in this area.'. Also, I change the structure of the table 1.
   3. Figure 3: no explanation is given to the quantification of the factors listed on the x-axis. This omission is serious.
   - I explained that 'the comparison of each factor's relative importance (percentage) is shown in figure 3'. Also I changed the name of figure 3 to 'Figure 3. The comparison of each factor's relative importance'. In addition, I gave the quantification of factors of the listed on the x-axis.

4. Figure 4: again, no explanation is given to the quantification of the factors listed on the x-axis. This omission is serious.
- I explained that 'Table 4 shows the comparison of each factor's relative importance (percentage) in their current practice to reject old parts.'. Also I changed the name of figure 4 to 'Figure 4. The comparison of factors' relative importance in rejecting parts for remanufacturing'. In addition, I gave the quantification of factors of the listed on the x-axis.
   5. Table 6: the construct of Table 6 is ambiguous, the use of the symbol '/' in the box is not standard.
- I explained that 'The symbol '✓' indicates the intersection between the academic gaps and industry needs from our case studies as shown in table 6.'

Reviewer B:

Major review comments:

The case study described in the paper provides valuable insights on decision making processes of the recovery process management in automotive remanufacturing industries.

Minor review comments:

1. At page 4, "Guides (2000)" should be "Guide (2000)".

- I changed "Guides (2000)" to "Guide (2000)".

2. At page 6, what is the difference between Figure 1 and Figure 2? Is the difference only the customers of the two companies?
- Yes.
   3. At pages 6 and 7 (Table 3), please provide the definition of "shelf life of products". Is it different from "the maximum time allowance of remanufactured products in their inventory"?
- I changed " shelf life of products " to " physical life of products".
   4. In Tables 5 and 6, what does the sign "/" mean? Because it is not clear for me, I could not figure out what the tables are meant to describe.
   - I explained that 'The symbol '✓' indicates remanufacturing challenges found in the remanufacturing system.'
   - I explained that 'The symbol '✓' indicates the intersection between the academic gaps and industry needs from our case studies as shown in table 6.'