

Automotive Parts Remanufacturing – Experience of Polish Small Companies

Paulina Golinska-Dawson*, Monika Kosacka and Anna Nowak

Faculty of Engineering Management, Poznan University of Technology, Strzelecka 11, Poznan 60965, Poland

**Corresponding author. E-mail: paulina.golinska@put.poznan.pl*

ABSTRACT

Small- and medium-sized enterprises are the majority of European companies, including in the remanufacturing sector. Although automotive parts have been remanufactured for decades, becoming a common business practice, many problems remain. Empirical studies on small- and medium-sized remanufacturing enterprises are limited, with most of the research papers presenting case study results. In this paper, we aim to compare theoretical findings with empirical results from a bigger group of enterprises. We investigated small-sized automotive remanufacturers in order to identify everyday challenges in supplies of cores and the remanufacturing process.

Keywords: Remanufacturing process, Small-sized enterprise, Challenges, Operations.

INTRODUCTION

Remanufacturing is an industrial process that transforms used or broken-down product to restore its useful life and achieve as-good-as-new functionality (adopted from Lund, 1996; Hammond et al., 1998; Parkinson and Thompson, 2003; Sundin, 2004).

The remanufacturing process is more complex than the primary production process of the same product. The used or broken-down product must first be inspected to assess the feasibility of remanufacturing, then disassembled and cleaned. Components are reprocessed or substituted with new or reconditioned parts. All components are then re-assembled into the remanufactured product and tested. A flow chart of the remanufacturing process is presented in Figure 1.

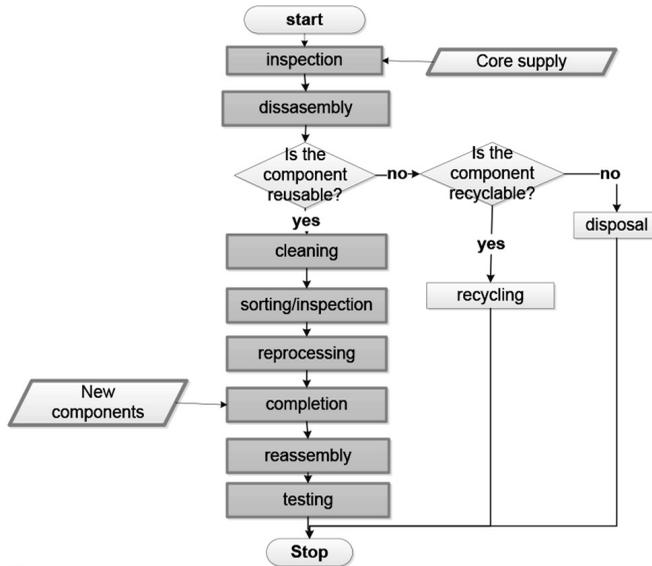


Figure 1. Example of remanufacturing process flow.

Remanufacturing companies, especially small- and medium-sized, face problems achieving adequate economies of scale and operational excellence (Golinska and Nowak, 2015).

The literature includes reports on the number of problems in logistics and operations management. We have classified them as follows:

- cores supplies,
- organization of the remanufacturing process,
- sales and demand management.

Cores are the equivalent of raw materials in primary production (Golinska et al., 2015). A core has multiple modules that are materially recycled, reused, refurbished, or disposed (Jayaraman, 2006). A number of researchers have noted the problems of cores supplies (Hammond et al., 1998; Guide, 2000; Sundin and Bras, 2005; Ostlin and Ekholm, 2007; Rubio and Corominas, 2008; Souza, 2008), including:

- uncertainty in quality, quantity, and timing of cores' arrival,
- insufficient availability of good quality cores,
- high product variability and small order sizes,
- variation in the rate of materials recovered.

An efficient cores management is the backbone of all remanufacturing processes (Subramoniam et al., 2010). According to Lind et al. (2014), achieving a steady flow of cores is challenging.

The second group of problems focuses on process perspective. The challenges presented in the literature can be classified as (Guide, 2000; Seitz and Peattie, 2004; Kim et al., 2008; Saavedra et al., 2013; Gagnon and Morgan, 2014;):

- uncertain lead times,
- small batches of a wide range of product variants and generations,
- materials matching restrictions,
- time consuming disassembly, cleaning, reprocessing, and reassembly,
- problems meeting variable quality requirements.

Sales and demand management problems focus mainly on matching supply with demand, and on pricing and marketing of the remanufactured products. Sales and demand management problems are not discussed in this paper.

This paper presents the results of a survey of Polish small-sized enterprises that remanufacture automotive components.

MATERIALS AND METHODS

Survey method

Figure 2 presents the research scope. This study focused on two problem areas: “cores supplies” and “organization of the remanufacturing process”.

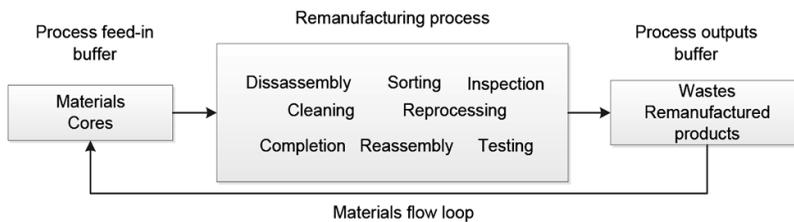


Figure 2. System under study.

We applied the Östlin (2008) approach, which divides the operation of remanufacturing into two processes – internal and external. The external remanufacturing process covers the operative and logistics operations performed before or after the internal process. To better define the border of the research, the “core supplies” were perceived from a “feed-in” buffer perspective for further internal process. The relations within the remanufacturing closed-loop supply chain were not taken into consideration. That simplification was based on a summary of the findings of Östlin (2008), Lundmark et al. (2009) and Barquet et al. (2013) who proposed integrated models for remanufacturing systems with supply chains and/or reverse supply chains. Their research, based on case studies, highlighted the differentiation of remanufacturing supply chains. Um et al. (2008) and Oiko et al. (2011) confirmed that remanufacturing can be performed by different actors in the supply chain, classified as original equipment remanufacturers (OEM), third parties like independent remanufactures (IR), or subcontractors (CR – contracted remanufacturers). Therefore, different supply chain models should be applied in each case. Some authors identified even more types of remanufacturing supply chain models (e.g., Lind et al., 2014). To provide a homogenous framework for our research, we excluded the supply chain relationship perspective in designing the survey.

The methodology incorporated the following steps:

1. Search for companies and create company database,
2. Verify company data by phone interviews,
3. Develop research questions and validate with small-sized remanufacturing company and academic experts,
4. Update the questionnaire and design an online survey tool,
5. Distribute the survey to small remanufacturing companies by emails,
6. Collect data,
7. Analyze data, and
8. Write research report.

The companies were identified by an Internet search of the APRA database (filtered for Polish companies only). Because the number of companies was not sufficient, we also used the Google search engine with the following keywords: remanufacturing, automotive parts, and regeneration. To verify the Google results, we conducted brief phone interviews to confirm each company's size and scope of its basic business operations. From these searches and verification, we created a database of 70 companies. (Official data about the size of the automotive remanufacturing sector in Poland is lacking.)

We based the initial structure of the questionnaire on our findings from the literature review and previous case studies conducted by the authors. The initial questionnaire was validated with a small-sized remanufacturing company to check the accuracy and clarity of the questions. After receiving the company feedback, academic experts reviewed and modified the questionnaire.

We used an online questionnaire, designed as a Google Docs application, to collect the empirical data. The questionnaire consisted of open-, closed-, and semi-open questions. We used both a numerical threshold (for quantitative questions) and Likert scale (for qualitative questions). The survey was designed to find answers to the following research questions:

RQ1: What are the main sources of the cores? Do small remanufacturers diversify the sources of supplies to buffer against uncertainty in quality, quantity, and timing of cores' arrival?

RQ2: Is product variability high in the case of small remanufacturers?

RQ3: Do small companies struggle to meet industry standards for material recovery rate?

RQ4: Are lead times for orders easy to predict in the case of small remanufacturers?

RQ5: Do small remanufacturers suffer from small batches of a wide range of product variants and generations?

RQ6: Do small size remanufacturers experience problems with materials matching restrictions?

RQ7: Which operations are the most time consuming in the case of small remanufacturers?

RQ8: Do small remanufacturers experience problems meeting quality requirements as stated by clients?

Data collection and sample testing

The questionnaire was distributed in electronic format to all 70 of the companies in the created database. We phoned the companies to make sure that they had received the survey and understood the questions. We collected the data both online and during phone interviews (using an online tool to enter the answers given by the respondents, if the company representative indicated that he/she was too busy to complete it online or was not familiar with online surveys).

RESULTS

We received 40 (out of 70) completed surveys, for a response rate of 57%, which was satisfactory. In order to verify the size and structure of our company group, we performed power analyses and calculated the required sample size. To achieve a confidence level of 95% (1- α) and a high test strength of 1- β = 0.9, the sample should consist of at least 37 companies. With 40 completed surveys, our sample was sufficient to provide further analyses.

All of the respondents employed less than 50 people, and remanufacturing was their primary business. The respondents were located in 12 out of 16 Polish administrative regions, so representative of the national perspective. Table 1 presents company experience in automotive parts remanufacturing in Poland.

Table 1. Respondents experience in automotive parts remanufacturing.

Period of time	Percentage	Number of respondents
< 5 years	10%	4
5-10 years	20%	8
> 10 years	70%	28

Most of the companies were operating in the automotive remanufacturing sector for more than 10 years. The companies remanufactured typical aftermarket products like: alternators, turbochargers, steering gear, cylinder heads, brake calipers, and pumps.

We provide below the analysis of the results for each of the defined research questions.

RQ1: What are the main sources of the cores? Do small remanufacturers diversify the sources of supplies to buffer against uncertainty in quality, quantity, and timing of cores' arrival?

The sources of the cores are presented in Figure 3. The majority (>75%) of the cores come from Poland.

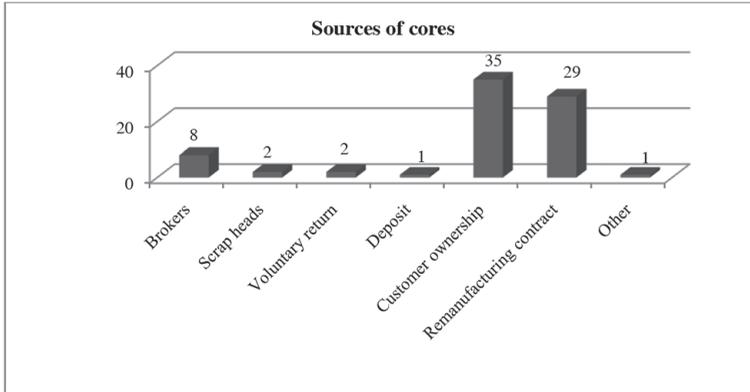


Figure 3. Sources of the cores.

Most of the companies remanufactured with cores delivered and owned by customers or by the OEM/OES. This approach helps to mitigate the uncertainty associated with availability of cores. The other approach to mitigate the uncertainty associated with cores delivery is diversification of the sourcing. The majority of analyzed companies diversified the supply of cores –72.5 % of the companies had more than one source of cores supplies (see Figure 4).

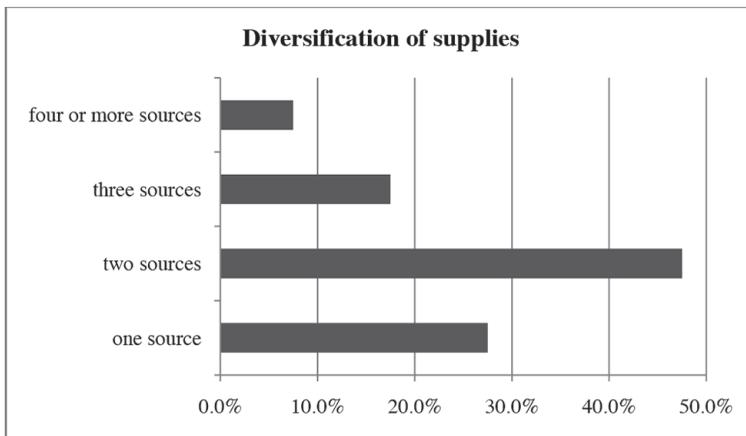


Figure 4. Diversification of the cores supplies.

RQ2: Is product variability high in case of small remanufacturers?

The respondents confirmed the theoretical statement that they suffer from a high variety of product models. The respondents explained that even when they remanufacture only single product groups (e.g., alternators), they still have to deal with hundreds of different variants of product and different generations. The majority of orders (87.5%) were for one piece (see Figure 5). Because customers' orders differ significantly, each order is processed as a separate production lot.

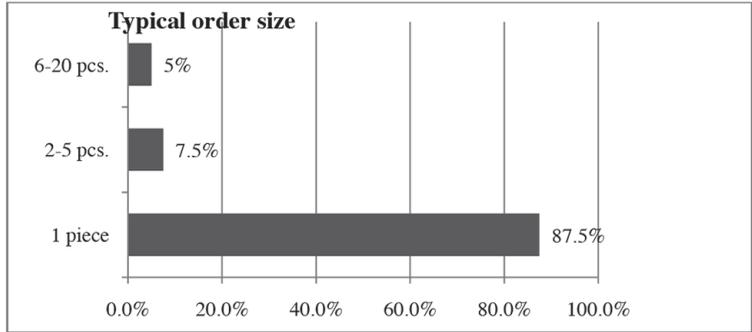


Figure 5. Size of typical order.

RQ3: Do small companies struggle to meet industry standards for material recovery rate?

The current standard for the material recovery rate in automotive aftermarket remanufacturing is over 85% (see www.apra-europe.org). The analyzed companies declared recovery rates as indicated in Figure 6. The majority of the analyzed companies (82.5%) met the industry standard and obtained a remanufacturability rate over 85%. Only 5% of respondents reported recovery rates below 80%, primarily due to very old cores.

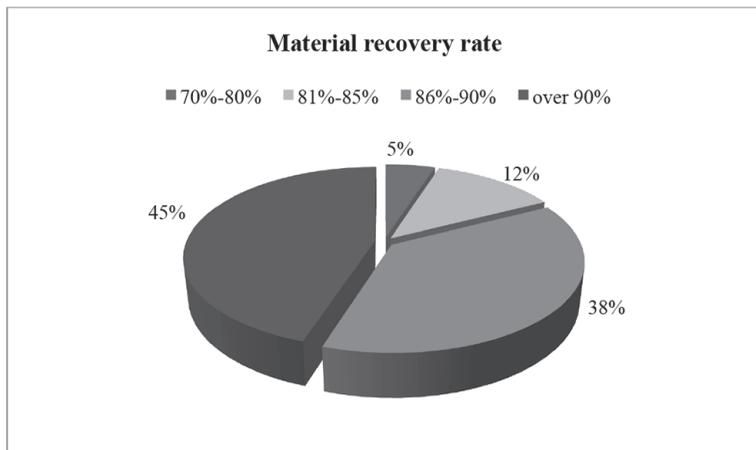


Figure 6. Material recovery rate values (MRR).

RQ4: Are lead times for orders easy to predict in the case of small remanufacturers?

The respondents stated that the remanufacturing process lead-time is rather unpredictable, varying from hours to weeks. They explained that the lead-time depends mainly on the technical condition of the core and the availability of spare parts to replace the worn-out components.

RQ5: Do small remanufacturers suffer from small batches of a wide range of product variants and generations?

We received very similar answers as in RQ 2. The majority of companies (87.5%) struggle to reach lot sizes of more than one piece. The large variety of products variants made it impossible to automate some of the operations or to apply line organization to the remanufacturing process. All operations were manual and required advanced technical skills. The respondents complained about difficulty finding suitably skilled employees. The lack of economies of scale also affected remanufacturing costs. Companies stated that due to the constant flow of cheap automotive parts from emerging markets (e.g., China) the cost attractiveness of remanufactured products is falling.

RQ6: Do small size remanufacturers experience problems with materials matching restrictions?

Materials matching problems are widely discussed in the literature. Fifty percent of our respondents reported these problems to a significant degree (answers 3-5 on Likert scale, see Figure 7). In follow-up interviews, some of the small remanufacturers indicated they were used to in-house engineering to suit the parts, because they remanufactured very small and differentiated orders. Materials matching problems were more common for the larger-scale remanufacturers, where partly automated processes required a constant flow of spare parts.

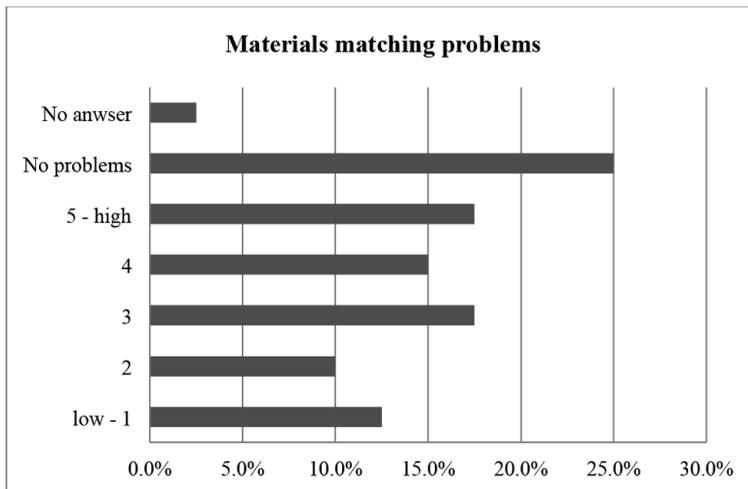


Figure 7. Materials matching problems.

RQ7: Which operations are the most time consuming in the case of small remanufacturers?

Most respondents listed more than one operation, so we summarized the results and divided them by the total number of answers. In our survey, approximately 45% of respondents indicated one operation as the most time consuming; for the remainder, it was a combination of two or more operations (e.g., disassembly and reassembly). According to almost 34% of respondents, the most time consuming operation was reprocessing of particular components. Cleaning was the second most time consuming (22.5%). Disassembly and reassembly operations were also mentioned as time consuming (see Figure 8).

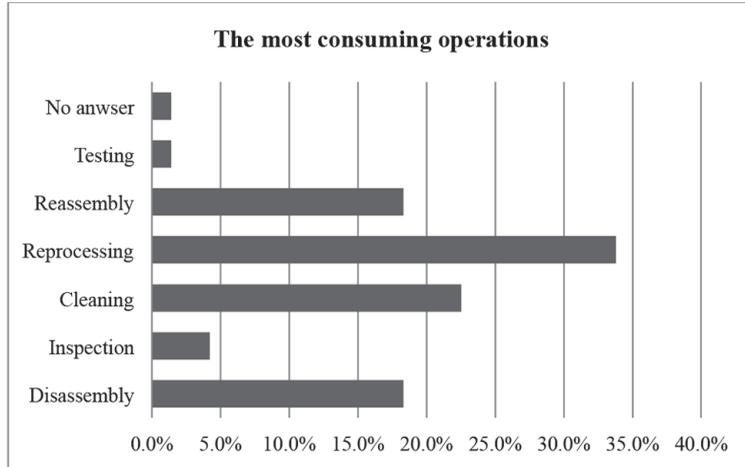


Figure 8. Most time consuming operations (Golinska et al., 2015).

Our results are partly consistent with Kim et al. (2008), who identified reprocessing and reassembly as the most time consuming operations. However, in contrast to our study, they reported cleaning and disassembly was perceived as not difficult or time consuming. This difference might be related to the small lot sizes, which are more time consuming, in the case of our respondents; this is typical of small size companies.

RQ8: Do small remanufacturers experience problems meeting quality requirements as stated by clients?

This question was assessed on a 5-point Likert scale. Detailed results are presented in Figure 9.

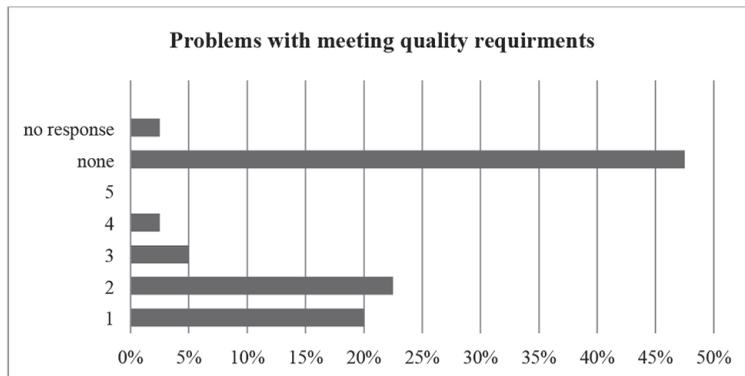


Figure 9. Meeting quality requirements.

Of our respondents, 47.5% did not experience problems meeting customer requirements; 20% indicated such problems were small (1 on Likert scale); and 22.5% referred the problems of meeting quality requirements as rather small (2 on Likert scale). None of the respondents indicated large problems meeting

quality requirements (5 on Likert scale). The majority of respondents had few or no problems (none or 1-2 on Likert scale) meeting customer quality requirements.

DISCUSSION

We classified the identified theoretical problems into three categories: core supplies, organization of the remanufacturing process, and demand and sales management. In this paper, we presented the eight research questions related to the first and second group of problems. In the case of the third group, namely “demand and sales management”, the majority of respondents (over 90%) did not report any problems with demand for their products. The main reason for this was that they remanufactured to order (RTO) and very often provided remanufacturing services for individual customers or for other companies. Previous studies confirmed this. They concluded that a low or unstable demand for remanufactured products negatively affected the companies, due to customers worrying about the quality of remanufactured goods and the poor structure of the sales channel when product ownership is only transferred during the sale (e.g., Ijomah et al., 2007; Guidat et al., 2015).

The results of RQ1 showed that Polish small remanufacturing companies try to diversify their source of supplies to overcome problems addressed in the literature as “uncertainties about the quality, the quantity and the time of return of the used product” (Hammond et al., 1998; Guide, 2000; Sundin and Bras, 2005; Ostlin and Ekholm, 2007; Rubio and Corominas, 2008; Souza, 2008). However, their approach is not proactive. They mainly rely on the cores, which are owned by the individual customers or by OEM/OES (remanufacturing contract). This situation is sufficient to meet the current demand, but might be a barrier to extend operations in the future. The OEM companies in the remanufacturing sector show an increasing interest in remanufacturing by themselves, which might result in fewer remanufacturing contracts for small companies in the future. The experts estimated that due to the growing importance of the circular economy concept, the demand for remanufactured products will be growing. The lack of independent supplies of good quality cores might be a barrier for extending the operations in the future.

An important problem that the small-sized remanufacturers in Poland experienced was the lack of economies of scale. This issue was addressed in research questions RQ2 and RQ5. Guidat et al. (2015) stated: “The processes of remanufacturing are difficult to standardize partly due to the variability of components parts, products and processes”. Our findings confirmed that statement. The Polish small remanufacturers suffer from very high variability of product variants, which influence the profitability of their operations and limit the application of more efficient organization of the internal remanufacturing process (for example, line production or optimal lot size).

Guidat et al. (2014) examined the challenges and barriers for different types of remanufacturing in networks. They proposed networking as a remedy for the lack of economies of scale in the case of small- and medium-sized remanufacturers.

The examination of the networking potential of the small- and medium-sized remanufacturers might be an interesting step for further research.

Research question RQ4 provided rather limited information. The numerical data was not sufficient to provide reliable answers on the remanufacturing lead-time in the case of small automotive remanufacturers. The respondents stated that the remanufacturing process lead-time is rather unpredictable, but mainly avoided providing detailed information, saying that the lead-time is strongly case-dependent. They stated that even in the same product families, the lead-time might vary from hours to days or even weeks, depending on the technical conditions. The literature also does not provide much insight, as most studies report on individual cases that cannot be generalized (e.g., Seitz and Peattie, 2004; Sundin, 2004).

Materials matching restrictions were addressed in RQ6. Our research showed that 50% of respondents perceived the problem as valid (answers 3-5 on Likert scale). Most of the respondents (over 90%) remanufacture to order. In such conditions, companies operate with short scheduling cycles and poor visibility regarding replacement components. The order release is generally organized as a one-to-one system. That means that every received core should be remanufactured. Despite these difficult organizational conditions, almost 25% of respondents said that they do not experience materials matching problems. This was a surprising result for us. However, in-depth interviews revealed that because the companies remanufactured very small and differentiated orders everyday, they were used to needing to do in-house engineering to suit the parts. The materials matching problems, however, should not be dismissed. They can be an important barrier to extending the scale of operations and meeting future demand for products, as well as managing the supplies of new parts and components. The materials matching problems are more crucial to larger-scale remanufacturing, where partly automated processes required a constant flow of spare parts.

The literature has reported highly variable processing times for remanufacturing operations along with time-consuming processing (e.g., Guide, 2000; Sundin, 2004). Kim et al. (2008) conducted a survey of automotive parts remanufacturers in the UK, Germany, France, and USA. They examined the economic and environmental aspects of remanufacturing operations. One of the problems they surveyed was the processing time of particular remanufacturing operations. They found that both reconditioning and reassembly were time consuming. In contrast, they found cleaning and disassembly accounted for only 20% of the remanufacturing process, and were relatively less time consuming and problematic as a result. Their research focused mainly on alternators and starters remanufacturing. These two products allow for relatively large lot sizes, in contrast to our sample companies. Moreover, our sample of 40 companies was much larger than the 10 companies of Kim et al. (2008). In our study, disassembly and cleaning operations were more time consuming for companies processing small lot sizes. Our results are consistent with Sundin (2004), who identified disassembly and cleaning as time consuming.

CONCLUSION

Current environmental regulations focus more on recycling regulations and reduction of hazardous substances. A growing number of end-of-use and end-of-life products enter the reverse supply chains of many companies and communities every year. The future supply and demand trends show that reverse supply chain management will require a shift to more efficient recycling recovery options. Remanufacturing is an environmentally preferable recovery option for products with high residual value (e.g., computers, machinery, and automotive parts) that can contribute to a more sustainable economy. In Europe, remanufacturing is mainly focused on the car industry, but slowly spreading to other industries (Guidat et al., 2014). Despite a long tradition of automotive parts remanufacturing (since the 1940s), empirical studies are still rather limited. The literature shows a number of problems relevant to automotive remanufacturers. We focused on small-sized enterprises, which are a majority of European companies.

In this paper, we aimed to compare theoretical findings with the empirical results coming from a bigger group of small enterprises in Poland. The main contribution of our research was providing empirical evidence for previous theoretical statements regarding core supplies and remanufacturing operations organization. Table 2 compares the problems found in the literature with those from our survey.

Table 2. Comparison of literature findings and survey results.

Domain	Problem	Research question	Finding in survey
Core supplies	Uncertainty in quality, quantity, and timing of cores' arrival	RQ1	Respondents apply a diversified supply policy to buffer against this
	High product variability and small order sizes	RQ2	Confirmed by respondents; the majority remanufacture one-piece orders
	Variation of the rate of materials recovered	RQ3	Respondents are able to meet industry MRR standards
Process organization	Uncertain lead times,	RQ4	Confirmed by the respondents
	Small batches of a wide range of product variants and generations	RQ5	Confirmed by the respondents
	Materials matching restrictions	RQ6	Confirmed by the respondents
	Time consuming disassembly, cleaning, and reprocessing	RQ7	Confirmed by the respondents
	Problems meeting variable quality requirements	RQ8	Not confirmed by the respondents

This paper aimed to reveal the current state of remanufacturing operations for small remanufacturers in Poland. The limitation of our study is that the supply chain perspective was simplified. More information would be needed to illustrate management of the entire supply chain of the automotive part remanufacturing industry. The relationships in the supply chain automotive remanufacturing industry are not sufficiently presented in our survey. To the best of our knowledge,

an extended supply chain survey of the automotive remanufacturing industry is not available in the literature. Some relevant information can be found in Lind et al. (2014) and Ostlin (2008), who examine how to secure the flow of cores by making agreements with core suppliers. The problem of supply chain management for remanufacturing is very complex, because both forward automotive supply chain and reverse supply chain must be taken into consideration. Moreover, the design of the supply chain is highly dependent on the remanufacturer type. For future research, we will extend this study to include in-depth studies on the relationships in the remanufacturing automotive supply chain in order to create a supply chain management model for the remanufacturing industry in Poland.

ACKNOWLEDGEMENTS

This work was supported by grant funds from the Narodowe Centrum Badan i Rozwoju NCBiR (National Centre for Research and Development) in the framework of the German-Polish cooperation for sustainable development, project "Sustainability in Remanufacturing Operations (SIRO)", Grant no. WPN/2/2012 and by a grant from Poznan University of Technology, the Faculty of Engineering Management, no. 503215/11/140/DSPB/4134.

REFERENCES

- Barquet, A. P., H. Rozenfeld, and F. A. Forcellini. 2013. An integrated approach to remanufacturing: model of a remanufacturing system. *Journal of Remanufacturing* 3(1): 1-11. doi:10.1186/2210-4690-3-1
- Gagnon, R. J., and S. D. Morgan. 2014. Remanufacturing scheduling systems: an exploratory analysis comparing academic research and industry practice. *International Journal of Rapid Manufacturing* 4(2-4): 179-198. doi:10.1504/IJRAPIDM.2014.066030
- Golinska, P., and M. Kosacka. 2014. Environmental Friendly Practices in the Automotive Industry. In P. Golinska (ed.), *Environmental Issues in Automotive Industry* (pp. 3-22). Springer Berlin Heidelberg. doi:10.1007/978-3-642-23837-6_1
- Golinska-Dawson, P., and A. Nowak. 2015. The survey on cores supplies in the SME in automotive remanufacturing. *LogForum* 11 (1): 51-61.
- Golinska-Dawson, P., M. Kosacka, and A. Nowak. 2015. The Survey on the Challenges of Organization of Automotive Component Remanufacturing in Small-sized Companies in Poland. In: *Toward Sustainable Operations of Supply Chain and Logistics Systems*: 241-254, Springer Verlag, Berlin Heidelberg. doi:10.1007/978-3-319-19006-8_16
- Guidat, T., M. Uoti, H. Tonteri, and T. Määtä. 2015. A classification of remanufacturing networks in Europe and their influence on new entrants. *Procedia CIRP* (26): 683-688. doi:10.1016/j.procir.2014.07.033

- Guide Jr., V. D. R. 2000. Production planning and control for remanufacturing. *Journal of Operations Management* (18): 467-483. doi:10.1016/S0272-6963(00)00034-6
- Guide Jr, V.D.R., R.H. Teunterand, and L.N.Van Wassenhove. 2003. Matching demand and supply to maximize profits from remanufacturing. *Manufacturing & Service Operations Management* 5(4): 303-316. doi:10.1287/msom.5.4.303.24883
- Hammond, R., T. Amezquita, and B. Bras. 1998. Issues in the automotive parts remanufacturing industry: a discussion of results from surveys performed among remanufacturers. *Engineering Design and Automation* 4/1998: 27-46.
- Ijomah, W. L., C.A. McMahon, G.P. Hammond, and S.T. Newman. 2007. Development of design for remanufacturing guidelines to support sustainable manufacturing. *Robotics and Computer-Integrated Manufacturing* 23(6): 712-719. doi:10.1016/j.rcim.2007.02.017
- Jayaraman, V. 2006. Production planning for closed-loop supply chains with product recovery and reuse: an analytical approach. *International Journal of Production Research* 44(5): 981-998. doi:10.1080/00207540500250507
- Kim, H. J., S. Severengiz, S.J. Skerlos, and G. Seliger. 2008. Economic and environmental assessment of remanufacturing in the automotive industry. *LCE 2008: 15th CIRP International Conference on Life Cycle Engineering: Conference Proceedings*. Sydney, N.S.W, 195-200.
- Lind, S., D. Olsson, and E. Sundin. 2014. Exploring inter-organizational relationships in automotive component remanufacturing. *Journal of Remanufacturing* 4(1): 1-14. doi:10.1186/2210-4690-4-5
- Oiko, O.T., A.P.B. Barquet, and A. Ometto. 2011. Business issues in remanufacturing: two Brazilian cases in automotive industry. In: *18th CIRP International Conference on Life Cycle Engineering, Braunschweig. Proceedings of the 18th CIRP International Conference on Life Cycle Engineering*. doi: 10.1007/978-3-642-19692-8_81
- Östlin, J. 2008. On remanufacturing systems: analyzing and managing material-flows and remanufacturing processes. Linköping University Dissertation.
- Östlin, J., E. Sundin, and M. Björkman. 2009. Product Life-cycle Implications for Re-manufacturing Strategies, *Journal of Cleaner Production* 17(11): 999-1009.
- Parkinson, H. J., and G.A. Thompson. 2003, "Analysis and taxonomy of remanufacturing industry practice", *Proc. Instit. Mech. Engineers Vol. 217 Part E: J. Process Mechanical Engineering*, 243-256, 2003. doi:10.1243/095440803322328890
- Lundmark, P., E. Sundin, and M. Björkman. 2009. Industrial challenges within the remanufacturing system. In *3rd Swedish Production Symposium 2009, Göteborg* (pp. 132-138).
- Rubio, S., and A. Corominas. 2008. Optimal manufacturing-remanufacturing policies in a lean production environment. *Computers & Industrial Engineering* 55(1): 234-242. doi:10.1016/j.cie.2007.12.009

- Saavedra, Y. M., A. P. Barquet, H. Rozenfeld, F.A. Forcellini, and A.R. Ometto. 2013. Remanufacturing in Brazil: case studies on the automotive sector. *Journal of Cleaner Production* (53): 267-276. doi:10.1016/j.jclepro.2013.03.038
- Seitz, M., and K. Peattie. 2004. Meeting the Closed-Loop Challenge: The Case of Remanufacturing. *California Management Review* 46(2): 74-8. doi:10.2307/41166211
- Sundin, E., and B. Bras. 2005. Making functional sales environmentally and economically beneficial through product remanufacturing. *Journal of Cleaner Production* 13(9): 913-925. doi:10.1016/j.jclepro.2004.04.006
- Sundin, E. 2004. Product and Process Design for Successful Remanufacturing. Linköping Studies in Science and Technology Dissertation No. 906, Production Systems, Department of Mechanical Engineering Linköpings Universitet, Sweden.
- Subramoniam, R., D. Huisingh, and R.B. Chinnam. 2010. Aftermarket remanufacturing strategic planning decision-making framework: theory & practice. *Journal of Cleaner Production* 18(16): 1575-1586. doi:10.1016/j.jclepro.2010.07.022
- Souza, G.C. 2008. Closed-loop supply chains with remanufacturing. *Tutorials in Operations Research*. INFORMS, Hanover. doi:10.1111/j.1540-5915.2012.00394.x
- Sundin, E., and O. Dunbäck. 2013. Reverse logistics challenges in remanufacturing of automotive mechatronic devices. *Journal of Remanufacturing* 3(1): 1-8. doi:10.1186/2210-4690-3-2
- Wei, S., D. Cheng, E. Sundin, and O. Tang. 2015. Motives and barriers of the remanufacturing industry in China. *Journal of Cleaner Production* 94: 340-351. doi:10.1016/j.jclepro.2015.02.014
- Um, J., J. Yoon, and S. Suh. 2008. An architecture design with data model for product recovery management systems. *Resources, Conservation and Recycling* 52: 1175-1184. doi:10.1016/j.resconrec.2008.06.001

none