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Remanufacturing challenges and possible lean improvements

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ABSTRACT

Remanufacturing is a viable way to prolong the useful life of an end-of-use product or its parts. Despite its economic, environmental, and social benefits, remanufacturing is associated with many challenges related to core (used product or its part) availability, timing and quality. The aim of this paper is to study how lean production could be used to tackle remanufacturing process challenges and contribute to shorter lead times. To meet this aim, we conducted a literature review and case studies of four remanufacturing companies. The case companies' remanufacturing challenges were: (1) a lack of material requirements planning system, (2) poor core information, (3) a lack of core material, (4) poor spare parts information, (5) a lack of spare parts material, (6) insufficient quality management practices, (7) large inventories, (8) stochastic remanufacturing processes, (9) a lack of supply-demand balance, and (10) insufficient automation. These challenges contribute to long and variable remanufacturing process lead times. To tackle remanufacturing challenges, seven lean-based improvements with a major effect on improvements in lead time were suggested: standard operations, continuous flow, Kanban, teamwork, employee cross-training, layout for continuous flow, and supplier partnership. Providing that the suggested improvements are implemented, a possible lead time reduction of 83–99 per cent was projected.

1. Introduction

Remanufacturing can be described as a series of manufacturing steps applied to an end-of-use part or product in order to return it to like-new or better performance, with warranty to match (CRR, 2007). Remanufacturing is becoming a critical element of a circular economy, where products are developed, manufactured, used, and recovered to prevent any sort of waste and reduce the extraction of raw materials. In Europe alone, the remanufacturing industry is estimated to generate billions of euros yearly; therefore, it involves encompasses significant financial and environmental benefits and offers opportunities to various stakeholders of the resource-efficient life-cycle system (Östlin et al., 2008; APSRG, 2014).

Nevertheless, despite successful growth into different industries, remanufacturing continues to face numerous challenges (APSRG, 2014). In 2015, the European Remanufacturing Network (ERN, 2015) underlined the challenges experienced by 188 European remanufacturers: lack of technology, lack of product knowledge, lack of sales channels, legislation restrictions, high labour costs, quality of feedstock, volume or availability, and customer recognition.

Lean production is one possible improvement strategy with which to address remanufacturing challenges. Lean delivers a set of principles and tools to gain operational efficiency, reduce process waste, and increase productivity in remanufacturing (Jacobs and Chase, 2001; Fargher, 2006; Sundin, 2006; Östlin and Ekholm, 2007; Pawlik et al., 2012; Kurilova-Palisaitiene et al., 2014; Vinodh et al., 2015). Lean production originates from the Toyota Production System (TPS) and has five goals to improve companies' performance: shortest lead time, best quality, lowest cost, best safety and high employee morale (Womack et al., 1990; Liker, 2004; Shah and Ward, 2007). While lean production has been successfully used in manufacturing companies (Fullerton et al., 2003), few studies have shown how lean production can help to tackle remanufacturing challenges, especially in terms of shortening lead times. Therefore, the aim of the present paper is to study how lean production could be used to tackle remanufacturing process challenges and contribute to shorter lead times.

2. Methodology

To fulfil the aim of the paper, we conducted a literature study and case studies at four remanufacturing companies.

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2.1. Literature study

The purpose with the literature study was to define the current state of the research in the area of remanufacturing challenges and the use of lean production in remanufacturing. The search phrases used for the literature study were 'remanufacturing', 'remanufacturing challenges' and 'lean remanufacturing'. We used a number of search and metasearch engines, including Science Direct, Scopus, Web of Knowledge, Journal of Remanufacturing and Google Scholar, to find relevant published works on this literature review.

In total, we found 590 papers published before February 2016 that met the above criteria. After reading the abstract of each paper and looking for the relevance in the paper's content and structure, we selected 174 papers with high relevance to remanufacturing challenges and lean remanufacturing. After reading the selected papers, we excluded a further 55 papers with diverging aim and findings. Consequently, 119 papers were used for the analysis in this paper. We also identified a further 11 relevant papers from the reference list of the 119 collected papers and included these in the literature review. The authors' previous experience and literature in remanufacturing and lean production was also used.

2.2. Case study

To study the complex phenomenon of remanufacturing challenges and improvement opportunities within a real-world context, a case study methodology (Eisenhardt, 1989; Yin, 1994; Law, 2004) was selected in this work. Yin (1994) emphasized that, through case studies one can generate theory from the interpretation of observations made in natural settings. Kuper and Kuper (1985) argued that more discoveries have arisen from single-case observations than from statistics applied to large groups.

In the present paper, the case study focuses on identifying remanufacturing challenges and possible improvements using lean production. These issues were studied at four companies by following standard case study procedures and applying the same data collection method, which enables a smooth cross-case analysis. The data collection method combined a focus group interview (Morgan, 1997) with the value stream mapping (VSM) method. The VSM method is often used as a mapping tool in Lean production to develop an overview of the production operations, including material and information flow as well as connection to the external stakeholders (Rother and Shook, 2003). In VSM, the main company's operations are schematically mapped in the actual sequence to reflect the production process steps, inventory, and other process-relevant information. With the help of VSM, companies are able to identify challenges and develop possible improvements (Jones and Womack, 2003). In the present study, the VSM method was used for visualization purposes in the data collection stage. Visual data representation enables transparent discussion and on-site data triangulation. The focus group interviews with VSM lasted between two and 3 h each and included five to seven company employees whose competences cover different functions, such as facility or process managers, planners, operators or technicians, administrators, sales, logistics, and quality managers. The sessions were recorded, transcribed and analysed using qualitative content analysis.

Four remanufacturing companies were studied using the case study methodology. The selected companies represent different business areas and products, ensuring a broader perspective on remanufacturing challenges and possible lean-based improvements.

Company A belongs to an original forklift truck manufacturer and provides remanufacturing services for original equipment manufacturer (OEM) rental and used forklift trucks. After remanufacturing, the forklifts are sold through a rental contract again or in a second-hand market under the standard known as 'approved used forklift' with a guarantee of three to nine months.

Company B is a contracted engine remanufacturer with a monthly demand for remanufactured engines from the OEM, which remains a supplier of spare parts. When the user needs to replace a broken or worn-out engine, the OEM offers a remanufactured one. Only after the remanufactured core is delivered to the OEM is a remanufacturing operation on the returned one initiated.

Company C is an independent IT remanufacturer of computers and smartphones. The key duties are to manage the inflow of cores, classify their quality and erase their data. Avoiding the disassembly and the following remanufacturing processes, computers that are approved for the highest quality category are sold to local end users, while computers of lesser quality are sold to resellers and remanufacturing companies throughout Europe.

Company D is a contracted remanufacturer of filling machines and operates in a business-to-business environment, with a throughput of one to three machines per year. The warranty period for remanufactured machines is six months and an additional performance warranty is provided. In terms of efficiency, the performance of the remanufactured machines is degraded by just 1 per cent compared to a new one of the same generation.

A brief overview of the remanufacturing companies is presented in Table 1.

3. Remanufacturing challenges identified from the literature review

Many researchers agree that remanufacturing is complex and difficult to manage due to a high number of internal and external uncertainties (Hammond et al., 1996; Guide, 2000; Lundmark et al., 2009). Internal uncertainties typically originate from the remanufacturer's internal process challenges, while external uncertainties depend on the challenges outside the companies' borders. Based on the literature review, we developed a three-level model of remanufacturing challenges (Fig. 1).

- *Industry level* refers to the challenges related to a remanufacturing industry (economic, environmental and political perspectives)
- *System level* refers to the remanufacturing system (closed product life-cycle system perspective)

Table 1
Overview of company characteristics.

Characteristics	Company A	Company B	Company C	Company D
Company size	Large	Large	Small	Large
Sector	Machines	Machines	IT equipment	Automotive
Product complexity	High	High	High	High
Remanufacturing experience	20 years	10 years	10 years	20 years
Remanufacturing business in comparison to manufacturing	Minor	Major	Major	Medium
Remanufacturing status	OEM	Contracted	Independent	Contracted