Human resource strategy in disassembly for remanufacturing

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Abstract
Studies on product disassembly for remanufacturing using strategic perspective have been overlooked in current studies. This research uses a strategic approach to examine how product, process and organisational design affect disassembly strategies among different remanufacturers. Three companies that consist of two automotive and one jet engine remanufacturers have been selected as subjects. A case study approach using qualitative data has been adopted to examine how remanufacturers design their disassembly strategies. Our analysis revealed that the two major factors influencing disassembly strategies are product complexity and the stability of supply of cores.

Keywords: remanufacturing, disassembly strategy, product and process characteristics

Introduction
Remanufacturing is a process where used products, which are referred to as cores are brought back to as-new condition. Remanufacturing companies have to manage uncertainties regarding when they will receive the cores *(time uncertainty)*, as well as their number *(quantity uncertainty)* and condition *(quality uncertainty).* These uncertainties lead to difficulties in remanufacturing operations particularly the disassembly phase.

The disassembly process in remanufacturing is important for several reasons. Disassembly is a key process in remanufacturing because without it, products cannot be remanufactured. Unfortunately, most products are designed to optimise the assembly process without considering the ease of disassembly after product use.

If returned products cannot be disassembled, product remanufacturing cannot take place. Although disassembly can be carried out, it does not mean it is an easy process or that it will be optimised. Given cores are not designed for disassembly for remanufacturing, every core might be defective in some way during the remanufacture process (Sundin and Bras, 2005). These conditions leads to many challenges during the design of a viable recovery system (Klausner et al., 1998). Consequently, the success of disassembly is a key success factor in remanufacturing operations (Sundin and Bras, 2005). In addition, disassembly is the main gate of information for most data related to remanufacturing operations (Guide Jr., 2000; Junior and Filho, 2012). This information is valuable to minimise uncertainties in every phase of remanufacturing (Ferrer and Ketzenberg, 2004; Ferrer, 2003).

Most current studies highlight disassembly as technical activities which break down cores into components without considering other factors such as employee skills, tools, equipment, product knowledge etc. Furthermore, the majority of those research utilise positivist paradigms using operations research with strict assumptions. Most of the research focuses on remanufacturing operations particularly production planning and control such as inventory control (Hsueh, 2011; Wu, 2012), demand forecasting (Shi et al., 2011) and production planning (Li et al., 2013; Poles, 2013; Wu, 2012) among others. However, they do not consider disassembly.

Bras and McIntosh (1999) suggest that research which investigates the practice of disassembly should cover organisational design, product characteristics and process design (see Figure 1). By incorporating these three factors, this research can investigate with comprehensive analysis and view disassembly operations as *a system*. In this system, there is a start and end point that can be used as boundaries. The starting point of disassembly system in this research is the point at which the disassembly shop floor receives information regarding the cores. As soon as the disassembly shop floor receives the information, facility set-up, tool selection, and job allocation can be carried out. At the other end, the end point of the disassembly system is when cores have been disassembled into components and the components have been put in designated areas either for further processing in remanufacturing operations, as stock, or for recycling. Boundaries and coverage of activities in disassembly system are important in understanding the context in which the disassembly strategy is adopted.

Research Objectives

As mentioned in the previous section, Bras and McIntosh (1999) assert that remanufacturing studies should cover three areas namely, organisational design, process design and product design. These are vital to a comprehensive investigation of the relevant factors affecting the disassembly operations. Of these three areas, organisational design is the least investigated in current literature. One of the studies focusing on this issue is Hermansson and Sundin (2005) who found that inter-functional communications across different departments, such as product design, logistics, remanufacturing, procurement, are important to manage uncertainties about return flow of the cores. However, the research gap to investigate organisational design with product and process characteristics remains. Issues such as types of relationship with Original Equipment Manufacturers (OEMs), employee skills (Kim et al., 2006) and information regarding know-how about the products (Gehin et al., 2008; Inderfurth, 2005) should also be covered.

Product characteristics are the most popular topic investigated in disassembly for product recovery but only limited studies have been devoted to disassembly for remanufacturing. Most studies that investigate disassembly are intended for recycling where a destructive disassembly method is acceptable. Disassembly for remanufacturing is different from that for other recovery methods because its resultant components should be feasible to be returned as-new condition. Hence, process requirements in disassembly for remanufacturing are higher compared to disassembly for other types of recoveries. Based on our literature review, we identify product characteristics that might affect disassembly strategy including type of materials (Johansson & Luttropp, 2009; Ryan et al., 2011), product structures (Srivastava and Kraus, 2010; Sundin and Bras, 2005), number of components (Smith et al., 2012), product variety (Hu et al., 2011), expected residual value (Xanthopoulos and Iakovou, 2009).

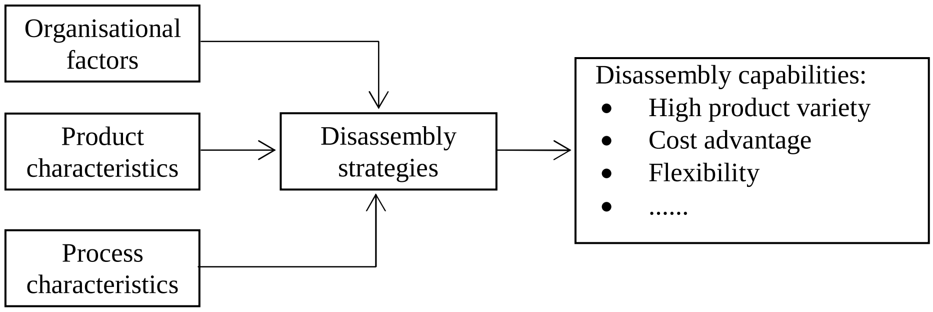


Figure 1. Research framework

Factors affecting process design for remanufacturing found in literature considered for this study are tooling and equipment (Seliger et al., 2002), employee skills, (Ayres et al., 1997; Tang et al., 2007), facility planning (Franke et al., 2006), capacity management (Franke et al., 2006), and cores volume (Wu 2012). These factors are interrelated and adoption of one factor sometimes drives companies to implement certain practices. For example, employing multiple workers would be more suitable if companies use multi-purpose tools and equipment. Literature also shows that remanufacturing is a labour-intensive industry that requires low skilled workers, multi-purpose equipment and flexible scheduling.

In this study we will investigate how remanufacturing companies manage those factors to develop disassembly strategies. Based on the preceding short discussion, the research question for this study is: ***How do companies develop operations strategies for disassembly in remanufacturing?***

The following sections will be organised as follows: firstly, the methodology will be discussed and companies selected as samples will be described. Next, a cross case analysis among case companies to compare differences and similarities will be covered. From this analysis, combining findings from this section into a single analysis in the next section will be attempted. Finally, we present limitation of this study and offer suggestion for future research.

Methodology

This study investigates the research question proposed in the outset using a multiple case study analysis. Case studies are appropriate when phenomena and the context cannot be investigated separately (Yin, 2009). In addition, this method is suitable for analysing questions of *why* and *how* related to contemporary events on which investigators have little control (Voss et al., 2002; Yin, 2009).

This study uses multiple case study design where three remanufacturing companies with different characteristics have been selected as subjects (see Table 2). Multiple case studies are preferred as opposed to single one as the former offers higher validity, reduces the tendency of observer bias, and augments external validity (Eisenhardt, 1989; Voss et al., 2002; Yin, 2009). Besides, multiple case studies allow researchers to develop replication and patterns matching through cross case analysis (Eisenhardt, 1989; Yin, 2009). The rationale for selecting these companies is that they form a continuum from the simplest to the most complex one. Based on a number of characteristics, company A represents the simplest while company C is the most complex.

Data is collected through interviews with company managers since they are the people responsible for managing disassembly activities. Shop floor visits, observations and document analysis (if available) were conducted not only to collect more data but also as a means to triangulate data from interviews. If there are some conflicting findings, confirmation is conducted until consensus is agreed. Triangulation using different sources of data is one of the methods to enhance validity (Eisenhardt, 1989; Yin, 2009).

Unit of analysis is the main entity that becomes focus of investigation(Yin, 2009). Although a formal statement of unit of analysis does not apparently influence the research outcome, Barratt et al. (2011) clearly stated that the unit of analysis offers several advantages. First, it helps researchers to identify relevant literature that is useful to analyse the phenomena under study. Second, it helps researchers to understand how the phenomena under investigations are linked to broader body of knowledge. Product is selected as the unit of analysis in this study as it enables investigators to identify patterns from the subjects. Too many differences in the subjects result in difficulties in identifying the emergence of similar patterns while too many similarities lead to difficulties to conduct cross case analysis since all subjects have similar patterns (Yin, 2009).

Analysis and Findings

Organisational Design

Among several organisational factors, the type of relationships with OEMs is the most important one since it influences other factors such as technical support regarding know-how about the products, volume of incoming cores, and early information regarding the cores. Of the three cases, Company C has a better position as opposed to Company B and A because it is an OEM. Both Company B and A are not OEMs but Company B develops contractual agreements with OEMs and receives higher support from them regarding technical know-how of the products. Company A also signs contractual agreements with OEMs but only for certain products.

In several ways, Company C is more advanced than the other two cases. The company requires advanced and specialised knowledge which is almost impossible for independent remanufacturers to acquire due to the high cost and advanced technology of the products. Different from remanufacturing companies in general where knowledge can be accumulated, in this company there are some points where skills and knowledge are classified as “expired”. This situation happens when the employee has not used his capability after a certain period of time. Qualifications of employees should comply not only with company policies but also regulations from regulatory bodies such as International Aviation Safety Association (IASA) and Civil Aviation Authority (CAA).

At the other extreme, Company A as the simplest one, employee do not require formal training and education to do the tasks. Skills are obtained through experience and peer coaching as a substitute to formal training and education. They are multi skilled workers that have flexibility to switch from one task to another. Company B requires slightly higher qualifications than Company A but much less advanced than Company C. This company develops a structured job matrix with 3-1-3 scheme. In this scheme, there are at least three employees that can do every job and each employee has 3 different skills to perform different jobs. This strategy allows a higher level of flexibility than in Company A but is still lower than that of Company C.

In industrial settings, OEMs have the highest access to customers in obtaining cores in comparison with other remanufacturing players. This fact is valid for company C. The supply of cores is stable so that the company is able to avoid idle capacity due to lack of cores. In terms of product complexity, jet engine is the most complex of the other three cases since there are thousands of different components with unique serial numbers that have to be rebuilt into the same engines. Also, there are many components that require certain treatment and specific skills are required to carry out these tasks.

Company A is a retail player with a small production volume based on direct orders from customers. Although the company has contracts with industrial customers such as insurance companies, taxi operators and OEMs, the majority of cores come directly from customers. These conditions lead to difficulty for the company in forecasting the number and arrival time of cores. Quite often, production volume is in units rather than in batch due to the small number of incoming cores. In case there is not any customer order, cores from storage are processed with the purpose of avoiding idle capacity and developing stocks of remanufactured products.

Regarding Company B, a contract remanufacturer, productions always start after orders from customers are received. Usually orders are in high volume so that the company can minimise fixed costs such as facility set up, tools and equipment preparations. Because productions run at high volume, job specialisations can be organised to a certain extent. Using this method, the company can minimise fixed costs through maximising the volume of production output.

Process Design

There is a considerable difference in terms of how to set up facilities between the three cases. Company C spent a large amount of investment to set up facility, both for physical and non-physical facilities such as R&D, training and employee certification. Even if the production volume is not as high as the other two companies, a large number of components within jet engines leads to a very complex remanufacturing process. Company C uses a product-oriented layout where different engines types are processed in different areas. This strategy is adopted to ease identification and separation of components from different engines. The main components that have a unique serial number on them should be reassembled into the same engines. To avoid idle capacity, Company C relies on robust forecasting and scheduling. The company even can refuse to reject cores if they are unable to remanufacture them. Again, early product information from the engine health management system helps to avoid idle capacity and over stock.

On the contrary, Company A uses a common area, tools and equipment, and any employees available to disassemble cores. This is due to its low level of product complexity in comparison to jet engine disassembled in Company C. The company carries out full disassembly regardless of the conditions of cores. Production volume is small and typically in units rather than in batches. To run production processes of small volume and high fluctuation, the company employs multi skilled workers who can switch between tasks easily to avoid idle capacity.

With regards to process design complexity, Company B occupies a position between Company A and B. Practically the same as Company A, Company B performs full disassembly to all received cores but with a more structured disassembly operations. They employ a research and development team to design customised tools and equipment for different product models. Different product models are disassembled in different dedicated areas that are equipped with customised tools and operated by employees with specific skills. As stated by one of the respondents, *"moving people is much easier rather than moving tools and equipment"*.

Company B undertakes sorting to identify obvious damage so that low quality cores are removed early and not processed further. Elimination of bad cores in the sorting process helps the company to streamline remanufacturing operations included in the disassembly stage. This process can run more smoothly without any disruptions due to the fact that low quality cores – typically requiring more work and special treatments are eliminated early from processing.

Product Characteristics

The expected residual value of components is another important factor in product characteristics that distinguishes Company C from the other two companies. A jet engine consists of high value components that require specific skills to perform different treatments for different components. The high value of jet engine materials comes from two sources: (1) the *type of materials* to make the components, and (2) *the manufacturing process* of the components. The main material in a jet engine is titanium, a precious, light, strong metal, which is expensive and incurs considerable costs in the complicated process of building the engine. Among these high value components, some of them require extremely careful treatments in isolated laboratories carried by specialists.

Products remanufactured at Company A and B are different and identical in some ways. The number of components of products in Company B is the same as those of Company A but there are higher product variations in the former. The number of components in a gearbox, transmission and automotive engine is considered moderate in comparison to other products that are popular for remanufacturing like printer cartridge. Company B has a higher production capacity, latest product types to remanufacture and a higher variety of product types. A combination of these features makes the disassembly operations more complicated. However, they have a more stable supply of cores in comparison to Company A. This is due to its contract relationships with OEMs that make the supply of cores more stable. Product types that are remanufactured in Company B are also more 'state-of-the-art' in comparison to Company A which remanufactures any model of gear box regardless of its year of production.

In general, profit margins per unit product in Company A are higher than Company B because each customer requires different services. As an example, consider the cost of the company service for transmission for a car that was produced in 1970s. Equipment and components are not available in the market and OEMs do not produce the component any longer. As a result, the company makes the component and charges a premium price to the customer. For orders that come from OEMs, both company A and company B more or less earn the same amount of profit per unit product but the quantity of orders in Company B is much larger than those in Company A.

Discussion on disassembly strategies

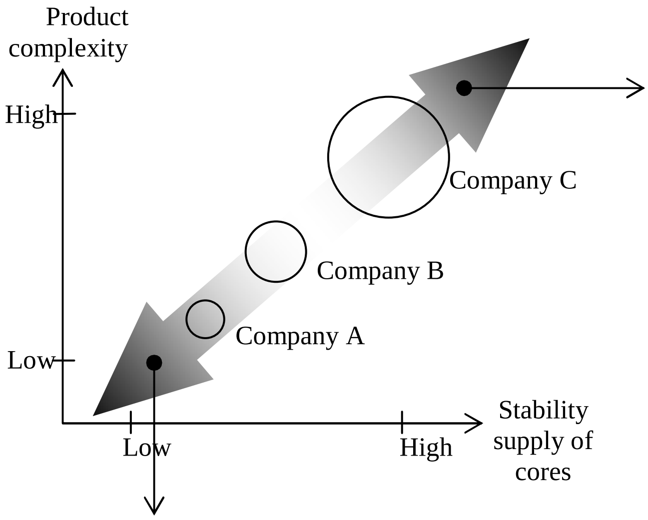
From discussion in the previous section, it has become clear that remanufacturers use different operation configuration to organise their disassembly system – e.g. worker flexibility, specialised tools and equipment, rigid production schedule, etc. In general, factors affecting a disassembly system can be classified into two broad categories: product complexity and stability supply of cores. These two factors are summary of product, process and organisational factors that affect disassembly strategies.

Table 1. Summary of Cross Case Comparison

	Company A	Company B	Company C
Organisational design			
Number of employee	35	75	625
Relationship with OEMs and cores sourcing	A contract remanufacturer for some products but most of the cores come from individual customers	A contract remanufacturer, all cores are supplied by OEMs who are also the customers	An OEM, company obtain cores as part of product service system offered to customers
Stable supply of cores	Relatively low stability, majority of cores comes directly from individual customers.	High stability due to the high volume of cores storage	High stability as it is part of product service system
Support from OEMs regarding	Does not receive support from OEM but develop knowledge based on experience	Obtains support from OEM regarding know-how the products	Possesses knowledge and information regarding know how of the products
Employee qualifications and knowledge acquisition	• Informal training through coaching and experience • Multiple skills to carry out different tasks • Employees are encouraged to be flexible workers	• Mechanical degree or some working experience would be an advantage. • Moderate level of job specialisation; the company adopts 3-1-3 policy	Requires formal education background, training, experience and professional certification
Process design			
Facility layout	Single facility for all types of transmissions and gearboxes	Shop floor is organised into several categories	Each shop floor is designated for specific different product type
Tools and equipment management	Generic tools and equipment that can be obtained from the market	Specific tools and equipment that are customised for different products to allow employees to work faster	Specific tools for different types of components and products
Level of disassembly	Full disassembly	Full disassembly	Partial and selective disassembly
Strategy to minimise idle capacity	Cores from storage are processed in case there is no order from the customer	Job rotations between different jobs and different products	Robust production scheduling and forecasting
Product design			
Operations	Focus on remanufacturing torque, gear box and transmission in small volumes.	Remanufacture gear box, transmission and car engine	Focus on remanufacturing jet engine as part of repair, maintenance and overhaul.
Number of components	Moderate, 100+	Moderate, 100+	High, 30,000-40,000 components depends on the engine types
Volume of production	Approximately 5,000 units per year	Approximately 18,000 units per year	Approximately 360 units per year
Product variety	Higher than company B. Company remanufacture any cores regardless of the types and models	Lower than company A. Only gearbox, transmission and engines for products that are still produced by OEMs	Five types of jet engines

Strategies adopted in the three case companies can be summarised as in Figure 2. Company A which is located at the bottom-left adopts the opposite strategies compared to company C which is at the top-right of the figure. Company C is an OEM and provides product-service system to its customers. Under this system, the ownership of the cores remains with the company whereas the customers pay the company based on power-by-the hour. Benefits of the system is that the company has better information regarding the condition of the cores, when the cores need to recover, which parts need to be replaced etc.

There are some exceptions to findings from literature. Theoretically, to adopt specialised skills and knowledge, a high product volume is not a compulsory requirement in the remanufacturing process. High product complexity, high value materials, and a high number of components are factors that contribute to adopting of job specialisation. A high complexity product needs longer time to disassemble and hence increases feasibility to use employees with specialised skills.



Key Strategies	Advantages
• Specific employee skills with specific tools and equipment	• Job specialisation leads to more efficient operations
• Manual guidance to do tasks is available formally	• Avoid cores damage during disassembly.
• Steady supply of cores and high production volume	• Minimised idle capacity and low fixed cost

Key strategies:	Advantages:
• General skills, only require minimum skills to perform tasks	• Worker flexibility
• Manual guidance to do tasks is not available formally	• Give employee empowerment
• Tools, equipment and facility are shared to disassemble different product types	• Low fixed cost to set up facility
• Transfer employee from one task to another to avoid idle capacity due to small production volume and stochastic supply of cores	• More efficient resource allocation

Figure 2. Summary of disassembly strategies

As can be seen from Figure 2, both Company A and B remanufacture similar types of products but Company B has certain advantages over Company A. The former is able to develop disassembly facility which has some degree of specialisation in terms of employee skills, tools, equipment and facility. This is largely due to high production volume minimising fixed costs from setting up more a specialised disassembly facility. In Company B, the fixed cost is minimised because of a high production volume. For example, to set up one of the shop floors requires approximately a total investment of

5,000 GBP. This fixed cost which will be spread over 5 years. This is considered a large spending for a company which is categorised as an SME. Considering this difference in strategy adoption, Company B and Company A have dissimilar cost structures although they remanufacture similar products. Company B bears a higher fixed cost to set up shop floors which will be used for long time whereas Company A incurs higher expenses for variable costs mainly for labour.

As discussed in the previous section, critical strategies for a company with lower product complexity and fluctuating supply of cores are employing flexible workers with multiple skills. These strategies permit companies to share resources and transfer employees between different tasks. Conversely, remanufacturers that disassemble complex products with steady supplies and utilise workers with specific skills, would be a preferable option. It does not mean that companies positioned in the top right corner do not need multiple skilled workers and those in the bottom-left corner do not require specialised skilled workers. Any company regardless of its position in Figure 2 needs these different types of skills albeit it with different combinations (Hermansson and Sundin, 2005).

Similar to conventional manufacturing system, remanufacturing companies adopt different capabilities to face competitors within an industry. Flexibility is an important capability in order to enable remanufacturers to disassemble various product types (Ostlin, 2005). This capability is important for companies located in the left-bottom corner of the graph whereas companies positioned on the right-top corner rely on fixed cost minimisation through rigid production schedule, idle capacity minimisation and streamlining production flows.

Limitation and Future Research Recommendation

This study investigates three companies, two from the automotive industry and one from the aerospace industry. Future studies could cover broader industries with different characteristics so that more patterns of strategies are identified and generalisation of findings improved. In addition, further investigations will be carried out regarding whether there are any specific competitive priorities for remanufacturers and how disassembly strategies are related to the competitive priorities.

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