Remanufacturing for the automotive aftermarket-strategic factors: literature review and future research needs

Ramesh Subramonim a,*, Donald Huisingh b, Ratna Babu Chinnamm c

a Office of Project Management, Delphi Product and Service Solutions, 5820 Delphi Drive, Troy, MI 48098, USA
b Institute for Secure and Sustainable Environment, University of Tennessee, 311 Conference Center Building, Knoxville, TN 37996-4134, USA
c Department of Industrial and Manufacturing Engineering, Wayne State University, 4815 Fourth Street, Detroit, MI 48202, USA

Article info

Article history:
Received 12 September 2008
Received in revised form 6 March 2009
Accepted 6 March 2009
Available online 1 May 2009

Keywords:
Sustainability
Aftermarket
Remanufacturing
Strategic Planning
Automotive
Supply chain
Reverse logistics

Abstract

While the concepts of remanufacturing and reverse logistics are gaining popularity in practice, the available literature and theory on strategic decision making in these areas are limited. This paper is designed to address this gap, in particular, for the automotive industry aftermarket. In doing so, the authors reviewed literature pertaining to: customer demand(s), product design and development, cost-benefit analysis of reman, core (i.e., used product) supply management, reman competencies and skills, product life cycle strategies, reman and reverse logistics network design, relationships among key stakeholders, environmental considerations, regulations, and impact of emerging economies. The literature findings along with our experience in working with automotive reman products were used as inputs to guide the formulation of seven major propositions for the strategic factors in decision making within reman. The propositions were then tested through a case study. The case study reconfirmed many of the factors like product life cycle, regulations, etc. from the literature review and also identified new factors like OE customer requirements. Our results provide a foundation for further research for companies that deal with Original Equipment (OE) Sales, Original Equipment Service (OES), as well as Independent Aftermarket (IAM) business in the automotive industry.

1. Introduction

Remanufacturing, or Reman, is an industrial process whereby used products referred to as cores are restored to useful life ([61]). Reverse logistics is a systematic process of planning, implementing and controlling the backward flow of raw materials, in-process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or proper disposal ([10]). Aftermarket support refers to activities associated with products (e.g. spare parts) and services (e.g. engine overhauls) after initial sale of a product ([53]). In the automotive aftermarket business, there is ‘Original Equipment Service’ (OES) product support with warranty and also ‘Independent Aftermarket’ (IAM) product support that is outside the warranty period.

The growing awareness of sustainability issues by consumers, businesses, governments and the society-at-large, is driving many industries to undertake environmentally conscious policies for their product development, manufacturing, distribution, service and end-of-life management. According to a survey of US and European executives, there is high business value in remanufacturing [36]. Numerous studies have also confirmed that reman is profitable for OEMs [24,63,22]. Fortune Magazine, in its recent special report [19], listed the top ten companies (Honda, Goldman Sachs, Continental Airlines to name a few) across various industries that are going beyond the law to operate in a more environmentally responsible way. Reman and the reverse logistics associated with them have gained significant importance because of this increased awareness. Reuse [52], a situation where the product is used again, results not only in economic benefits, but also in ecological benefits as well.

In many industries, currently, the strategic planning processes for reman aftermarket products are mostly based on a “push” type approach instead of a holistic approach that covers the pull of both the aftermarket and the original equipment (OE) divisions in an integrated way. For example, here are some of the findings from the automotive sector based on the experience of the authors in the reman field.

- There is often a misalignment between OE divisions on product design needs for reman [24]; this results in wasted efforts during reman or may lead to a failed business opportunity.
• There is often a lack of proper technical, environmental, and quality data within OE divisions to effectively convince new customers to use reman.
• OE divisions have a “mass production” mentality that do not fit well with the low volume reman requirements for replacement parts.
• Reman is not addressed as a “product value stream” approach, but as a service need after OE production.
• There is often a lack of a well-defined reman business case analysis model to assist the business managers to make timely decisions. Consequently, the program manager frequently makes belated decisions based on reman volume.
• There is a lack of proper metrics to measure the impact of missed reman business opportunities, including, “design for reman” business opportunities.

The current reman situation of the OE companies negatively impacts the long-term profitability and growth for aftermarket reman products. The revenue potential and the opportunities for developing more cost-efficient, customer-oriented aftermarket services emphasize the importance of integrating aftermarket strategies within all phases of the product life cycle for companies dealing with OE, OES and IAM. Aschner [3] found that environmental initiatives from major corporations are mostly specialist activities rather than mainstream business strategies. Such ad hoc solutions, in the absence of a strategic framework, lead to inappropriate and inadequate support for reman projects, and consequently, result in sub-optimization of the entire supply chain. There is therefore, an urgent need to better understand the holistic, strategic, decision-making framework for reman [59] in the automotive aftermarket industry. The holistic approach will help business leaders to make better strategic decisions to fulfill the requirements for the OES and the IAM customers. This manuscript is designed to address these issues.

The remainder of this paper is organized as follows: First, we report on literature review of the strategic reman planning factors using Rohde’s [55] supply chain planning matrix as a framework. In the process, we identify key strategic factors for the automotive reman aftermarket. Second, we propose and evaluate some key propositions through an exploratory case study. Finally, we propose a decision-support framework and identify key questions for future research.

2. Literature review of strategic planning factors for aftermarket reman

The literature review was designed to help us better understand the strategic factors that impact decision making in the automotive aftermarket reman business for companies dealing with OE, OES and IAM.

The supply chain planning matrix, illustrated in Fig. 1, classifies the typical supply chain planning tasks into the two dimensions of the “planning horizon” and the “supply chain process”. The term “Supply Chain Management” as defined by Oliver and Webber [50] emphasizes that only top management can assure that conflicting functional objectives along the supply chain are reconciled and balanced and stress the need for an integrated systems strategy. According to Fleischmann et al. [16], the strategic network planning (Long term) process deals with the setup of capacities and identification of profitable flows of materials, components, and final products. Since the decisions related to the network infrastructure commit the firm on the long-term and generally require investments of large amounts of capital, the strategic planning process is a task of the top management. In this context, this paper addresses the following strategic factors:

1. Product strategic planning processes.
2. Physical distribution structures
3. Plant location and production systems
4. Cooperation among reman supply chain stakeholders

2.1. Product strategic planning

2.1.1. Global reman market and regulations

The current automotive OEM business model of “build to forecast” is not conducive for remanufacturing growth from the supply side of the supply chain. There are emerging trends of “servicizing” business models [31] that will create the demand pull for remanufactured products. In a servicizing business model, end consumers (society-at-large) wish to avoid risk of ownership, expect better product upgrades at low cost, wish to have increased flexibility and are more environmentally conscious. This will result in more reman pull for the OE automotive suppliers like Delphi from the OE car makers. For the aftermarket business, the collision and repair shops will have incentives to return the cores to the OE suppliers to get an upgraded, low cost reman product for their customers.

Legislations such as the WEEE directive, ROHS, Sale of Good Act, End-of-Life Vehicle directive, Energy Using Products directive, and Freedom of Information Act [20] can be drivers and barriers for reman. In emerging markets like China, the impact of governmental regulations on reman designs was found to be minimal [69]. However, Hammond et al. [24], found, through their survey research, that increased part proliferation and new governmental regulations caused major changes within the reman industry. Webster and Mitra [66] analyzed the effects of governmental subsidies on sustainable operations. They found that governmental subsidies can increase reman activity; in this case, it is optimal if the policy maker divides the policy inputs between manufacturers and remanufacturers.

Mondal and Mukherjee [45] did an empirical investigation on the feasibility of reman activities in the Indian economy. Their analysis revealed that a lack of technical feasibility is the major reason for non-acceptance of reman in the computer and electronics industry, whereas, a weak legislation and customer’s negative attitudes towards the reman products prohibit accepting reman as a business option in many other industries. The authors also emphasized that reduced environmental awareness was a factor for low acceptance of reman products among customers in India. Ming [44] looked at sustainable practices in the Chinese automotive industry. He pointed out that insufficient development of high value-added and service operations in the manufacturing industry has resulted in low profits and tremendous consumption of new resources. A major reman company in the USA (ARI) went out of business due to a Chinese company making commodity products at very low prices [8]. The Chinese company could manufacture new parts and ship them to the US at a lower cost than the US company could reman them. These three papers highlight the generally very low amount of reman effort in the two big...
emerging economies to support the current, fast paced growth in manufacturing.

In Europe, until 2002, vehicle manufacturers had the lion’s share of the OES business. The EU automotive block exemption regulation opened up business opportunities for part suppliers. The impact of this new regulation varies from country to country, since the aftermarket distribution is still very closely linked to local culture [43]. Although economic margins are more attractive in the independent aftermarket, there are also higher costs in terms of marketing, packaging, sales, etc. Companies such as Bosch, Denso, Delphi, and Valeo have developed their own networks to maximize profits. Seviye [58] found in his study of the GM service parts organization that regulations such as the take-back obligation introduce inefficiencies and limit product availability in the market. Government incentives for collection and disposal of products can help reduce such inefficiencies.

Increased environmental awareness has prompted the governments of some countries to develop regulations that can positively or negatively impact the reman sector. For example, in Brazil, South America, there is a regulation that prevents the importation of cores in order to promote more local manufacturing. This has a negative effect on OE companies to setup reman operations in the region if the cores are not easily available in the local market. If there is strong organizational reman partnership with the various supply chain players, it will lead to an increase in reman products. On the other hand, companies might choose a recycling approach to meet regulations and ignore reman as an opportunity. Availability of cheaper commodity products from emerging economies can also be a significant factor in reman decisions for companies. The impact of globalization and diverse legislation led us to develop the following propositions:

**Proposition 1.1a.** Global environmental regulations, with proper incentives, can have a positive impact on the decision to reman a product.

**Proposition 1.1b.** Availability of cheap new products from emerging economies negatively impacts the decision to reman products.

### 2.1.2. Intellectual property and non-OE reman competition

Pagell et al. [51] underscored the importance of end-of-life product management strategy for companies driven by rapidly changing customer expectations and stringent product take-back regulations. He predicted that while manufacturers may initially gravitate towards low cost strategies, they will consider other strategies like in-house disassembly to protect intellectual property (IP), at a later stage. He also pointed out that reman is the most desirable option, as it minimizes environmental impacts, results in less loss of value, protects IP and can create new market opportunities. Unfortunately, reman is not a feasible option for many supply chains because reman costs can exceed the price of new products or maybe the product life cycle is too short for reman. For the automotive industry, many short life cycle products could be brought back to life with future upgrades if the design for reman was fully implemented. Life cycle assessment studies have revealed that organizations must be careful not to reman products with obsolete or polluting technologies, but should strive for products that provide for the upgrade of embedded technologies [5].

Mazumdar et al. [41] discussed the postponement strategy in manufacturing as an innovative solution for manufacturing companies dealing with high product variety and demand uncertainty similar to the independent aftermarket. Aftermarket companies spent a lot of money in the past for demand planning tools [49] to avoid loss of sales. Now they realize that they have to keep the inventory low and meet customer demands through faster final assembly builds. This especially applies to aftermarket companies because of the increased difficulty in forecasting customer demand [1]. It is noteworthy that many after sales service products can be remanufactured on an as-needed basis using a postponement supply chain strategy.

The expansion of automotive electronics has forced many automotive suppliers to apply for patents to protect their IP. The very same automotive parts are subjected to counterfeit parts if left in the open for service and aftermarket. This can easily happen due to globalization, where patents are not protected in many emerging economies. These counterfeit parts can result in loss of intellectual property and brand erosion. This reasoning on brand erosion and intellectual property along with the conclusions from the previous sections led us to develop the following propositions:

**Proposition 1.2a.** The need to protect intellectual property has a positive impact on the decision to reman products.

**Proposition 1.2b.** Outside competition to reman products (or brand erosion) has a positive impact on the decision to reman products.

---

4 A postponement supply chain strategy is to store the base parts to assemble finished goods as required for customer requests and helps to reduce the quantity of finished goods stored. This is a great strategy, especially for the aftermarket, since there is a wide variety of parts and an uncertain customer demand.
2.1.3. Reman economics

Remanufacturing a part can reduce the life cycle costs for the OE manufacturer. The demand for reman products will increase in the coming years as the end consumers become more aware of climate change and its impact [42]. As climate change gains importance, environmentally conscious manufacturing like reman will increase as well. In the interim, companies have to focus on the economic benefits with proper tools and planning.

King et al. [32] used the Delphi technique to establish a robust research agenda for reman. They identified selling “use” instead of “products” as a novel business model to capitalize on the revenue potential for reman. The authors emphasized that those products of high energy use in the product usage phase might not be environmentally preferable to reman. The industrial survey of Hammond et al. [24] investigated the reman decision-making factors and found that the profit potential was one of the top factors that forced companies to reman.

Nasr and Varel [47] discussed the phases of a product life cycle and stressed the need for cost models that consider the entire life cycle of products. These decision-support tools provide cost models for the extended product life cycle and help decision makers to decide when or if they should invest in reman of any or all of the components of their products.

Thorn and Rogerson [63] discussed reman as a potential product retirement strategy and looked at the economic justification for reman. Whether to reman a product or not is a complex decision for many OEMs. This decision has to be based on financial aspects, and not just on environmental issues alone [22]. Moreover, since most US companies are not responsible for the final management of their products, diverting these products from landfills might not yield any direct financial benefit to the manufacturer. Reman operations undertaken without a sound monetary foundation will almost certainly fail. Failures of this sort not only cost money but also discredit the reman philosophy. Thorn and Rogerson [63] recommended that it is essential to use a multidisciplinary team for evaluating the economic benefits since no single individual will be in a position to know all the costs and benefits. Three different cost categories are used for decision making in traditional manufacturing. They are the direct material costs, direct labor, and the administrative overhead. The general assumption that the sale of a product must earn sufficient revenue to recapture all materials, labor and overhead and make a profit will not apply for reman products. If portions of a certain product can be returned multiple times, it may not be reasonable to capture all the material, labor and overhead in the first sale. The task will be even more complicated when trying to determine the costs and benefits of returning and of the preparation for reman.

Toktay and Wei [64] analyzed the impact of transfer pricing on reman for companies that have a decentralized structure with separate reman and manufacturing divisions. They conclude that a cost allocation mechanism that allocates a portion of the initial production cost as a fixed fee to the reman division, has the optimal financial results for the firm. Compensating the manufacturing division for accessing used products ensures that divisional incentives are aligned with those of the company.

The lack of proper financial reman cost-benefit analysis tools can result in inappropriate reman decisions. This is more important now since the majority of companies are making reman decisions based on economic benefits [19,22]. This need for proper reman financial tools as expressed by Thorn and Rogerson [63], along with the other literature findings led us to develop the following proposition:

**Proposition 1.3a.** Lack of proper financial reman cost-benefit analysis methods negatively impacts the decision to reman products.

2.1.4. “Green” image and reman market demand

The importance of aftermarket integration is increased by emerging “Green” responsibilities for, and management of, the end-of-life (EOL) phase. The EU countries, through diverse directives, are trying to regulate the EOL processing of electrical and electronic products and cars. The customer often looks at price, but it is more and more common that the customer chooses products that correspond with their ethics, such as those based on environmental issues [29]. The reman of products or parts is the most significant in terms of resource conservation and in economic terms primarily in relation to the aftermarket supply. The reman of automotive products in the current state accounts for two thirds of all reman according to Steinhilper [59].

The growing “Green” awareness can force the automotive OEMs to demand reman products from the suppliers in their contracts. On the other hand, reman is looked upon by many automotive OEMs as non-core business [56]. These findings of a growing “Green” awareness and market demand or customer acceptance [38] for reman products led us to develop the following propositions:

**Proposition 1.4a.** Increased interest to be a “Green” company has a positive impact on the decision to reman products.

**Proposition 1.4b.** Low market demand for reman products from the automotive OEM’s negatively impacts the decision to reman a product.

2.2. Physical distribution structure

2.2.1. Reverse logistics network

A reverse logistics network [15,17] for reman deals with how products are collected from the end user and returned to a facility for reman. Our literature review focused on the strategic, long-term factors for distribution, namely, network structure, transportation, distribution facility layout, design, and outsourcing.

Logistic and reprocessing arrangements for reman are organizationally different from mainstream product supply and distribution. There is increased interdependency that is reflected in the pressures on product designers to reduce the scale and costs of product variation, and more generally, to reduce materials and energy use [7] by improving product remanufacturability. Product designers also have to take into consideration issues in the aftermarket and (EOL) phases. For example, Seitz and Peattie [57] suggest that design engineers need to include aftermarket considerations within design briefs that reduce the inventory fluctuations that can negatively impact reman. Similarly, the designers need to avoid compound materials that cannot be recovered. In the current management practice, however, the aftermarket and EOL phases are loosely connected to mainstream production. That is why the integrated management of the total production system is needed to help ensure competitive advantage in the new economy.

Companies have to ensure that sufficient storage and handling capacities exist for returns handling. These requirements involve a number of decisions such as the number and location of take-back centers [25], product return incentives, transportation methods, etc. [21]. Companies also have to decide if dedicated facilities for returns handling are preferable [35]. The other key decision is to decide whether to outsource the core return processes. If the core return processes can be clearly separated from the forward process, it can be outsourced [10]. Examples include Sears and Kmart in the
US, where the returns are handled by Genco [11]. The value and type of products and existence of experienced third party companies are other determining factors.

Dowlatalshahi [13] proposed a strategic framework for the design and implementation of reman operations in reverse logistics. These strategic factors were cost, quality, customer service, environmental concerns and political concerns. The author stresses the importance of looking at strategic factors before operational factors and to focus upon the need for a holistic approach in decision making. While De la Fuente et al. [12] concluded that no new general processes are required at the strategic level in the integration of forward and reverse supply chain processes, more recent publications of [18,21,54] are arguing the importance of strategic factors. This is due to the growing realization that companies are not getting reverse logistic systems in place due to a lack of the firm’s understanding and capability in analyzing the strategic factors.

Georgiadis and Vlachos [18] observed that long-term strategic management issues on reverse logistics systems were not analyzed in the past, partly because of the difficulty in handling the variety of factors in the forward and reverse channels as well as due to the complexity of their interdependencies. There is increased uncertainty of obtaining the cores from the core brokers and collision shops to meet the need for the IAM product reman. The OES product reman is more certain and controlled due to the availability of exchange of cores from dealerships. Ren et al. [54] highlighted the challenges of the complexity of decision making for supply chain managers and the lack of guidelines for translating strategies into actions. The high speed of technology change is making electronic products obsolete faster; this results in a high volume of products for disposal adding to the already inflated disposal costs [62]. Companies should look at extension of useful life with strategies like reman to be competitive in the future. Here, Jayaraman and Luo [30] emphasize the importance of reverse logistics network in gaining competitive advantage.

In the automotive industry, the increased usage of electronics in automotive components has resulted in increased product recovery value. The high speed of technology change (and the resulting disposal costs) and the constant demand from the end consumers for upgraded products with shorter product life cycles make it more important than ever to do reman and to support it with a strong reverse logistics or product recovery network. These conclusions led us to develop the following two propositions:

**Proposition 2.1a.** A good reverse logistics network has a positive impact on the decision to reman an aftermarket/service part.

**Proposition 2.1b.** Technology change and the resulting increasing disposal costs have a positive impact on corporate decisions to reman aftermarket/service parts.

### 2.2.2. Product value and core management

Guide and Daniel [21] underscored the complexity of reman (as compared to traditional manufacturing) by specifically highlighting the uncertainties from stochastic product returns [65], imbalances in return and demand rates, the variable condition of the returned products, and the need for a reverse logistics network. Nasr et al. [48] found that the reman firms report core inventories of one-third of the total inventory carried due to uncertainties in quantities and timing of returns. The excess cores require costly storage space, high disposal costs and capital tied up in materials. The uncertainty in materials recovered is often measured as Material Recovery Rate (MRR). As noted by Guide and Daniel [21], MRR for returned cores is an important aspect in the decision-making process. He identified the need for remanufacturers to manage excess parts periodically with unique decision-making tools. Guide also emphasizes that the reman industry will face limited growth due to the lack of effective decision-making tools. The purchased parts (new parts) account for one-third of the parts on a fully remanufactured item resulting in waste. Subjective judgment and historical rates are currently being used in calculating purchase lots in about 75% of the reman firms. Nasr et al. [48] conclude with a reminder that the different characteristics identified in the paper should be dealt with as a whole and not separately because of the essential inter-relationships.

As discussed in Section 2.2.1, there is an increased product value in the automotive aftermarket due to electronics. The value of the product plays a major role in recovering the product. If it is too low, repair shops will throw the part away and charge the customer; resulting in supply problems in the reman chain. Core availability can be strongly influenced by product value and relationships in the reverse logistics network (e.g. take-back programs that encourage customers to return cores.). The automotive OE suppliers have a distinct advantage compared to independent remanufacturers in providing “seed stock” as cores during the initial stages of the program when returned cores are not easily available. Seed stock is typically composed of products that failed OEM specifications in the manufacturing plant and disassembled for reuse. New stock can also be used as an alternative to get the reman program started. This finding led us to develop the following propositions:

**Proposition 2.2a.** Increased product value plays a major role in recovering the cores and positively impacts the decision to reman an aftermarket part.

**Proposition 2.2b.** Good core availability through proper channel management is the backbone of reman and positively impacts the decision to reman.

### 2.3. Plant location and production system

The location of OE plants is generally based on OE customer needs. In the recent past, many OE auto component plants have been moved to countries with low labor costs and minimal environmental enforcement. This has led to a number of challenges, including long order lead times for customers. If the main source of returned products is the major customer for reman parts, then, the cost advantage of low cost countries has to be balanced with the resulting unnecessary transport of goods and the sunk costs for the setup of an offshore plant [16,34]. There are also the environmental burdens of plants operating in countries with low or non-existent environmental and worker health and safety rules and regulations. A low volume reman service or aftermarket operation is different in terms of volumes and layout compared to high volume OE production. These low volume facilities require more manual disassembly, parts cleaning, etc. compared to heavily automated high volume parts. This often results in a need for dedicated facilities anyway for reman plants. An effort to relocate reman plants overseas just for cost reasons alone can conflict with the objective of a short lead time requirement for aftermarket service parts. But in the case of reman parts, the reman plants can be located in the customer’s region and the logistical network can be local due to the fact that the cores are coming back from the customers for service and aftermarket. We conclude that a regional reman operation will be a benefit for aftermarket companies to provide low cost, short lead-time components for service and aftermarket parts irrespective of the OE plant location. Consequently, we offer the following proposition:

**Proposition 3.0.** A regional reman operation, irrespective of the OE plant location to support the local customer base has a positive impact on the decision to reman a service/aftermarket part.
2.4. Cooperation among reman supply chain stakeholders

The aftermarket has been an important source of revenue for OEMs such as manufacturers of civil aircraft engines and vehicles [57]. In the latter case, poor profits from vehicle manufacturers associated with excess production capacity in the industry contrast with aftermarket activity which generates significant profits for vehicle manufacturers and their retail network. Integration of aftermarket activity with the earlier life cycle stages reflects the influence of several factors discussed later in this paper. This effort requires a close cooperation among reman supply chain stakeholders such as the society-at-large (environmentally conscious), government (regulatory reman incentives), OE automakers (promotes reman), OE supplier division (promotes reman design), OE supplier aftermarket division (promotes reman) and reman core brokers (partners).

We identify design for reman and organizational structure as the two major drivers that influence an aftermarket company’s decision to do reman.

2.4.1. Design for reman

Hammond et al. [24] found core availability, assembly/disassembly [4,40] and design simplicity as the top three factors that make an automotive product difficult to reman. Seviye [58] highlighted the importance of core remanufacturability for GM Service part operations at the end of the seeding period. Indeed, availability of durable cores is key to the reman process. This can be achieved through better, upfront product design investments.

Lund and Denny [39] discuss the benefits and problems of extending product life cycles. For example, they state that unless an OEM is doing the reman, there is little incentive to design products for reman. Nasr et al. [48] reported that three-quarters of the reman products are not designed for disassembly and that this has a significant negative effect on reman operations. Seitz and Wells [56] wrote about the contradictory focus from the product designers and the aftermarket divisions. Product designers create product differentiation and the aftermarket divisions of the OEM’s look for standardization. The authors emphasize a more holistic approach (cross-functional and cross-organizational) that includes design for reman and environment. King and Burgess [33] recommended the use of a reman platform design as a strategic response to the directive on Waste Electrical and Electronic Equipment (WEEE). According to the authors, a platform design approach is one where a base platform is designed so that it can be used as the basis for a family of derivative products. The common components are high value parts that can be remanufactured to reduce cost and the parametric components can be easily adapted to suit different customer’s needs.

The role of the government as a reman stakeholder is explored in this paragraph within the eco-design context. Zuidwijk and Krikke [70] analyzed the strategic response of the industry to environmental regulations such as the WEEE directive. The WEEE directive makes OEMs and importers legally bound to take responsibility for post-consumer products. There were two responses studied: product eco-design and recovery strategies such as post shredder strategies. The authors proposed a modified WEEE directive to help make companies take more proactive approaches to eco-design. This finding supports the investigation of Yu et al. [69] on the perception and readiness of companies for implementation of WEEE and ROHS (Restriction of the use of Hazardous Substances) in China. The findings indicate that the extent of the companies’ responses largely depends on their market structure and client requirements. There is little evidence that these directives have, until now, driven the companies towards eco-design of their products.

This phase of the literature review emphasizes the importance of considering eco-product design [23,28] for reman from a combination of ecological, economic and customer considerations. A product designed for reman by the OE division will result in more reman products for service and the aftermarket. This will result in more revenue with increased aftermarket products, more profit with less cost for service and aftermarket, and will support the growing environmental awareness of businesses and end consumers. It will help to reduce the energy, materials and other negative environmental impacts of production waste [2]. Based upon these findings, we offer the following proposition for eco-product design for reman:

**Proposition 4.1a.** An OE product, that is Eco-designed for reman has a positive impact on the decision to reman a service/aftermarket part.

2.4.2. Organizational structure

Lund and Denny [39] did pioneering work on organizational structure to provide an overview and advice to potential remanufacturers. Lund and Skeels [37] identified product selection, marketing strategy, reman technology, financial aspects, organizational factors and legal considerations as issues to be considered for companies starting reman operations. For example, the authors identified some unique issues for OEMs that consider reman. They include: feedback of reliability and durability information, taking advantage of a manufacturer’s reputation for quality and advantages over independent remanufacturers in the form of manufacturing data, tooling and access to suppliers. Williams and Shu [67] studied the waste streams in the reman value chain of electronic products and used the reasons to stimulate corporate leadership to create design for reman policies.

Hermansson and Sundin [27] also emphasize the importance of organizational factors involved in reman. The authors divided the organizational structure into physical and non-physical areas. In the physical area, issues about the physical structure like the flow of cores, the high value parts, customers and logistics were central, while the non-physical areas pertain to employees’ competence, skills and leadership. The authors stress the importance of flexibility (by combining the OEM and reman operations) and strong communication between departments for a successful reman organization. Haynsworth and Lyons [26] provide a vision for how OEMs can begin to take advantage of reman opportunities by using proper marketing, product design and distribution systems. A minimum total cost of ownership for the full product lifecycle approach was recommended by Brent and Steinhilper [6] for companies involved with manufacturing and reman operations.

The literature review identified the importance of organizational structure policy issues like total cost ownership, a product life cycle focus, an integrated product marketing, product design and distribution as keys to reman success. In order for a company to have a successful reman strategy, it must be integrated within OE divisional business, as well as its service and aftermarket businesses. It has been documented that a late reman effort in the value chain significantly reduces successful reman launches in the service and aftermarket. Furthermore, the company needs to maintain good relationships [9] among the reman supply chain stakeholders like core brokers for a successful reman business. This insight led us to make the following proposition:

**Proposition 4.2a.** A well-integrated physical and non-physical organizational structure with the OE divisions and external

---

5 Seeding period is the time during which new stock is provided when reman cores are not available.
suppliers has a positive impact on the decision to reman a service/aftermarket part.

The literature review focused on long-term planning and addressed the strategic factors for automotive aftermarket reman and reverse logistics in the following categories of the supply chain planning matrix.

1. Product strategic planning processes;
2. Physical distribution structures;
3. Plant location and production systems;
4. Cooperation among reman supply chain stakeholders.

The supply chain planning matrix provided an excellent framework for the authors in researching the long-term planning factors. The literature review identified and confirmed the scarcity of information specific to the strategic factors for the automotive aftermarket reman value chain. It was also clear during the literature review that a deeper understanding of the factors through a case study will confirm the findings, shed light on any gaps, and also may potentially add/delete to the already established propositions. These factors apply directly to the OES and IAM reman products and can be used to build the decision-making framework once validated through a case study or a survey. A case study approach was selected for this paper for the reasons explained in Section 3.

3. Case study for testing the strategic factors in reman

The analysis of a supply chain and managerial issues therein are highly unstructured problems that can be dealt within exploratory design using case studies [57]. Yin [68] proposed an exploratory case study aimed at defining the questions and hypotheses of a subsequent study or defining the feasibility of the detailed research procedure. Furthermore, Yin [68] suggested a single case as a critical example if: 1) it forms an extreme or unique case, e.g. if not many cases are available; 2) if it forms a typical or representative case; 3) if it is a revelatory case, where the investigator has an opportunity to observe and analyze a phenomenon; 4) if it provides a longitudinal case; and 5) if it stands as a pilot in a multi-case setting. Yin [68] also suggests that within a certain case, one or more units of analysis can be studied, thereby, providing second replication logic.

A single site exploratory case study for two different products was conducted as Yin [68] suggested, for an example automotive company to evaluate the appropriateness of the propositions of this paper based upon reasons (2) and (3) above. The case study is used to assess the strategic factors from the literature review and to clarify the questions that require further research. A representative case was selected with two different products; the investigators had the opportunity to observe and to analyze the processes involved.

The company studied in this case study, is one of the major automotive suppliers that is currently involved with OE production, OE service, and independent aftermarket business. Within this company, only a small number of people make key strategic decisions regarding reman. The case study was conducted through semi-structured interviews with five business managers (OE Service & OE P&L responsible managers, IAM & OES program managers, Reman Operations Manager) and the Reman Service Engineering Manager who are the key decision makers. Company documents and other data, such as program information, were also used to confirm the findings.

Stuart et al. [60] proposed a five-stage research process (Fig. 2) for conducting case study research and was followed for this case study. The two products selected were extreme cases. Product "A" was an already established reman product for service and was recently considered for the independent aftermarket. Product "B" had OE customer requirements to reman for service, but had not yet been considered for aftermarket reman. The strategic factors identified during the interviews are shown in Figs. 3 and 4.

1. Research question: the research question was to determine the strategic reman decision factors for a company involved with OE production, OE service, and Independent Aftermarket business. The products had OE production facilities in North America. The products represented two extreme cases: 1) One product was OE produced and then accepted for OE service reman and then for the independent aftermarket. 2) The other product had a strong pull from the OE customer for reman initially and was considered for reman.

2. Instrument development: the OE division, the reman facilities, and the aftermarket division are located in the United States for the example products; this ensured access for the investigators to do 'face-to-face' interviews with the OE and aftermarket divisional managers. The investigators spent time at the reman location and interviewed the reman operation manager. These plants and divisional visits helped the investigators observe in real-time, the issues associated with the reman strategic decision-making process.

3. Data gathering: for data collection, four semi-structured 'face-to-face' interviews were conducted with the strategic decision makers. The two products chosen represented the extreme cases for strategic reman decision making.

4. Data analysis: data analyses were performed by transcribing the interview data and checking interview protocols with the participants. The findings were also confirmed with the company staff (Program managers, OES P&L responsible manager) to further validate the findings. A second important mode of data analysis was done by comparing the results of the research with other research findings (literature review identified the initial set of factors) and staff members, who served as additional elements in the data triangulation. In some cases, cross-checking was done with the reman operations staff (Reman Operations Manager, Core Manager) to obtain multiple perspectives on the data.

5. Dissemination: the products used in this case study were electronic products that have numerous opportunities for future growth in the automotive industry. The products being electronic, seem to be promising reman options for the company. Mostly, the products were selected for reman based on economic reasons (Proposition 2.2a). The cost-benefit analyses for reman were a challenge since there was no good, established, repeatable process for carrying out the analyses (Proposition 1.3a), in particular from a life cycle perspective (Proposition 1.3b).

Fig. 3 represents an electronic product launch for the OE division and the factors considered during the launch process as the
company moved from OE and OES to IAM products. Product A was already remanufactured for OES, but not for IAM. It is very clear from the figure that many strategically important factors for reman, like reverse logistics for IAM and product life cycle issues, were not quite considered during the OE product development stage. This resulted in reverse logistics problems during the IAM launch. Even when the product was considered for OE service, design for reman was not fully considered by the OE engineers resulting in sealed units (Not easy to disassemble) that are not easily remanufacturable.

Fig. 4 represents an electro-mechanical product launch and the OE Company had customer requirements to do reman for service. It was clear that these customer requirements did not drive design for reman requirements all the way deep into the product since the electronic part of the product was not remanufacturable.

### 3.1. Findings and assessment of case study results

#### 3.1.1. Cooperation among reman stakeholders

It was found that there was lack of a “big picture” focus among the reman stakeholders; this included the OE customers, the OE division, the aftermarket division and the core brokers in the aftermarket/service reman process for both products A and B upfront in the OE process. Even though Product A was remanufactured for service, the reverse logistics networks proved to be a problem during aftermarket reman execution due to lack of cores in the aftermarket. This reverse logistics challenge could have been overcome if the product was planned for IAM reman upfront in the OE business process. Also the OE division lacked proper systems for the core accounting process and could not accept the risks involved in managing the cores. For both products, the OE division did not quite push the OE customer to consider reman designs even though the customer product application requirements were not reman friendly. Also, cost and durability (for underhood parts) were mentioned as key reasons due to which the product was not designed for reman. The cost and durability factors could have been addressed if more innovative design solutions were explored at an earlier stage. There was management consensus that if reman costs are considered for the full product life cycle (including service and aftermarket) and accounted for, there will be more acceptability for reman products for service.

If the product is initially designed for service reman, then it is more likely to work for aftermarket reman as well. The OES Engineering Manager felt that the design for reman should be taken into account at the beginning of the product development process before the OE contract is negotiated. Mostly, the product design applications are considered at the OE contract level. This level of coordinated effort requires a different organizational structure to integrate the OE and the aftermarket business and engineering teams during product design and the product launch processes (Proposition 4.2a).

#### 3.1.2. Plant location and production systems

The OE plant location was in North America for both products and the customer base in North America helped drive reverse
logistics in the region. As the OE customer expanded their operations to other regions for product A, the reman operation was shifted to help support the core requirements. There were many challenges in launching reman programs in other countries (Proposition 3.0). The non-availability of local reman experts, language barriers and local government regulations (covered under “Product Strategic Planning”) resulted in the need for the OE Company to provide those skills from overseas to support the launch of the reman efforts.

3.1.3. Physical distribution structure

The late launch of reman IAM products resulted in a core availability problem as explained earlier for product A (Proposition 2.2b). The physical distribution structure or in other words, facility layout, design and outsourcing needed to be taken into account in the product design phase and when it is launched for OE customers. This level of proactive approach will result in better reman execution for service and aftermarket.

3.1.4. Product strategic planning

The new overseas government regulations to control reman parts resulted in a delayed launch for product A. These regulations were a result of the local government’s effort to control counterfeit products (Proposition 1.1a). Also to be kept in mind is the special treatment offered by the overseas governments for their industrial parks. The reman facility was located in one of the industrial parks, which helped launch the reman program faster since the government had approved the industrial park to do trial runs for the recycling economy. It was also revealed during the case study that many emerging economies like South America and India do refurbishing of parts from junk yards in privately owned workshops for automotive products. These parts tend to be lower in price compared to the branded reman aftermarket parts of the OE suppliers try to sell in those markets. Governmental regulations to “certify” reman parts and to enhance customer awareness for assured quality, can help reduce the impact of these low quality parts in the local market and thereby, support OE reman products.

The lack of a well-defined business case analysis tool also hindered the company from making the timely reman decisions (Proposition 1.3a). The case study results show that for both products, the company did not consider the total product life cycle when the reman business case was completed (Proposition 1.3b). It was interesting to note that Product B had OE customer requirements to do reman for service, whereas Product A had concerns from the OE customer to expand reman due to safety reasons. So the OEM customer demanded a warranty on the reman service part for both Subramaniam et al. / Journal of Cleaner Production 17 (2009) 1163–1174

Fig. 4. Case study – Product B (electro-mechanical module).
The interviewees agreed with all the developed propositions saying that they are all important for reman business decisions, but many of them were not currently considered. This feedback from the practitioners supports the potential value of the propositions. The case study results also helped to clarify the research needs pertaining to availability and usage of better decision-support tools, framework and strategies.

The following three propositions were developed by us based upon the new insights obtained during the case study and are explained in the subsequent paragraphs.

**Proposition 5.** The lack of reman friendly product application requirements from the OE customers negatively impacts the decision to reman a product.

**Proposition 6.** Good buyback incentives or lease programs for products at the OE divisions positively impacts the decision to reman products.

**Proposition 7.** Lower remaining service life and therefore, the lower potential volume requirements at the aftermarket stage, negatively impact the decision to reman.

As discussed in the case study, the lack of reman friendly product application requirements hurts the OE supplier to fully reman the product. This was identified as a gap in the cooperative effort between the OE supplier and OEM. A cooperative dialogue between the OE supplier and the OE customer upfront could have helped the supplier to get more reman friendly product requirements from the OE customers. This led the authors develop Proposition 5.

The OE divisions setup the buyback incentives or lease programs for the cores with their potential customers during the OE contract negotiations for both products A and B. If these programs are not properly setup, the ability for the aftermarket division to provide reman for OES or IAM will become more difficult. These findings led the authors develop Proposition 6.

As OE automotive suppliers try to expand their portfolio of reman IAM products in the current state (without an upfront reman strategy), the remaining service life requirements become a key factor in their decisions to do reman. If the remaining service volume is too low to support a viable business case, reman production will not happen. This can be a major challenge these days since the automotive OEMs are extending their warranty requirements to a maximum of 10 years, in some cases. This problem can be partially addressed by an earlier reman approach integrating the OES and IAM volumes that can provide the necessary volume for a successful business case. If not, the independent aftermarket reman manufacturers will fill that gap. This finding led to Proposition 7.

The current economic crisis and the declining automotive volumes definitely add pressure to OE suppliers and force them to be in a survival mode from the supply side of the supply chain. The job losses and the resulting delayed vehicle repairs have also squeezed the aftermarket business from the demand side. When we emerge from the recession, there will be more focus immediately on repairs; this will result in increased demand for aftermarket reman parts. All these trends should help the OE suppliers, if they are willing, to establish an increased presence in the global reman market.

4. Conclusions and future research work

A thorough review of the available literature in the fields of remanufacturing and reverse logistics and a current assessment of the automotive aftermarket industry identified the key factors and assessed the need for a holistic decision-making process at the strategic level for automotive reman OE companies. Propositions were generated and preliminarily tested through a case study. These propositions are the key factors that drive reman for the OE companies that have business models in all the three areas (OE, OES, IAM). The case study helped the authors of this paper to discover additional factors that were not considered prior to the study. The case study also helped the authors to confirm other factors that are important in the reman decision-making processes.

This research focused on automotive aftermarket reman (OES and IAM) for the OE companies. These companies need to take a “sustainable development” approach as defined by the World Commission on Environment and Development (WCED).6 By keeping sustainable development in mind, manufacturing companies are forced to satisfy customer needs in a manner that lead to a product life cycle perspective, less raw material extraction and consumption as well as reduced energy consumption. One of the means to achieve this is to design or adapt the products for product recovery [46], where parts of the product or whole products can be refurbished after being used (Reman). This thought process needs a circular material flow mentality for supply chain management rather than the linearity that dominates consumer society today. A strategic reman effort for the automotive aftermarket reman companies should be supported by a framework (Fig. 5) to reduce the environmental impacts of products and processes associated with industrial systems, with the ultimate goal of sustainable development along with the economic benefits of reuse. In light of the findings of this paper, the following questions for future research are presented:

- How can the strategic supply chain planning process for reman products be improved with better visibility of the entire, complex, dynamic system [14] for companies that produce OE, OES, and IAM automotive products?
- How should the new automotive aftermarket reman decision-making framework, be conceptualized and implemented to help business leaders better accomplish business system objectives and goals, in the short and long-term future?
- How can design for reman be more fully integrated upstream within the OE divisions to make more reman products available for service and aftermarket?

6 In 1987, the World Commission on Environment and Development (WCED) stated the concept of sustainable development as a “development that meets the needs of the present without compromising the ability of future generations to meet their own need.”
- How can remain be integrated into the mainstream business for the automotive aftermarket OE companies with a sustainable development framework (with less toxic material use, less life cycle energy consumption, less raw material usage, etc.) while maintaining or enhancing economic benefits along the entire chain?

References


