

Aftermarket remanufacturing strategic planning decision-making framework: theory & practice

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ABSTRACT

The authors of this paper offer an aftermarket, remanufacturing (or reman) decision-making framework (RDMF), developed, based on a comprehensive set of strategic factors (Subramoniam et al., 2009a) derived from an in-depth literature review and case studies. RDMF is also grounded on results from an industry survey and related theory. The survey targeted Original Equipment (OE) suppliers that are involved in automotive OE production and also provide remanufactured (or reman) parts for the aftermarket, which includes the Original Equipment Service (OES) and/or the Independent Aftermarket (IAM) business. A response rate of 42% was obtained for the survey; the respondents were business unit managers or chief engineers from 18 companies in the United States and Europe who are actively involved in the reman businesses. The survey results helped the authors of this paper to prioritize and confirm the strategic decision-making factors from previous research. The key factors considered to be important by more than 50% of the survey respondents, constituting roughly 79% of the strategic factors were then incorporated into RDMF. The RDMF will be useful for aftermarket supplier companies in general and in particular, will be useful for automotive suppliers, involved with OE and aftermarket production.

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1. Introduction

The growing awareness for sustainability issues by consumers, businesses, governments and the society-at-large, is driving many industries to undertake environmentally conscious policies and procedures for their product's design, development, manufacturing, distribution, service and end-of-life management. In this context, according to a survey of US and European executives, there is high business value in remanufacturing (Little, 1998). Remanufacturing, or Reman for short, is an industrial process whereby used products, referred to as "cores", are restored to useful life (Subramoniam et al., 2009b).

Numerous studies have confirmed that reman is profitable for OEMs (Hammond et al., 1998; Thorn and Rogerson, 2002; Guide et al., 2003). For example, Fortune Magazine, in a recent special report (Going Green, 2007), listed the top ten companies (Honda, 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 reverse logistics have recently gained significant importance because of increased awareness by corporate leaders and improving government regulations. *Reverse logistics* is the 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 points, to a point of recovery or proper disposal (De Brito, 2004). *Aftermarket support* refers to activities associated with products (e.g. spare or used parts) and services (e.g. engine overhauls) after initial sale of a product (Phelan et al., 2000). In the automotive aftermarket business, there is *Original Equipment Service* (OES) product support with warranty and also *Independent Aftermarket* (IAM) product support that is beyond the warranty period. In the automotive industry, the strategic planning decision-making processes for remanufacturing aftermarket products are mostly based on a "push" type approach (Subramoniam et al., 2009a), without systematic planning under a holistic approach that covers the pull of both the aftermarket and the original equipment (OE) divisions, in an integrated way.

In the context of sustainability, Boons (2002) discussed the difficulty in coordinating supply chain players and provided

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a conceptual framework for sustainable product chain management. Several authors also attempted to develop a decision-making framework for reman and reverse logistics. For example, Dowlatshahi (2005) developed a strategic decision-making framework from the perspective of businesses primarily involved with reverse logistics. Linton and Johnson (Linton and Johnson, 2000) developed a reman decision-making tool for Nortel Networks that helped them to more efficiently upgrade products through the reman process. Extant literature is sparse when it comes to providing an effective, strategic reman decision-making framework for companies involved with both OE and aftermarket production. The authors of this paper developed a reman decision-making framework (RDMF) for suppliers, in particular automotive suppliers, with a sustainability focus. The RDMF framework is based on a comprehensive set of system-wide, strategic factors, derived from the literature review, case studies, and through validation via an industry survey.

2. Reman theory: a framework of sustainable supply chain management

‘Supply chain management,’ (SCM) was defined by Mentzer et al. (2002) as, “the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.” Based on this definition and an extensive review of the sustainability literature, Carter and Rogers (2008) defined sustainable SCM as “the strategic, transparent integration and achievement of an organization’s social, environmental and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains.” Despite numerous calls for theory development in SCM (Kent and Flint, 1997; Mentzer and Kahn, 1995; Meredith, 1993; Thorn and Rogerson, 2002), there has been limited attention to theory building research especially in the field of sustainable SCM until 2008 when Seuring and Muller (2008) identified the theoretical gaps. They identified theoretical gaps in sustainable SCM after an analysis of 191 papers in the field from 1994 to 2007 and concluded that there is inadequate treatment of ‘social’ issues in the existing research. They mostly focused on the forward supply chain without much consideration of reman or reverse logistics. Hutchins and Sutherland (2008) published an exploratory research article in the same year (2008) as Seuring and Muller (2008) that included social issues for sustainability in SCM decision-making. They proposed trial social indicators of labor equity, safety, philanthropy and health care for corporations. Their research (Hutchins and Sutherland, 2008) however did not cover reverse supply chain and/or reman issues. Carter and Rogers (2008) explored the integration of sustainability with SCM within a company’s corporate strategy and found that true sustainability happens at the integration of economic, environmental and social areas. The authors

however did not address the theoretical aspects of the reverse supply chain especially in an aftermarket reman setting.

Daugherty et al. (2003) focused on automotive aftermarket reverse logistics and explored trust and relationship commitment from the OEM suppliers to the customers; they found that reverse logistics performance improved with better commitment. Several other authors (Carter and Elram, 1998; Mollenkopf et al., 2007) advocated the importance of reverse logistics in a supply chain strategy. Hammant et al. (1999) modeled a strategic supply chain model for the automotive aftermarket and found that the industry will need fewer distribution centers to support the same customer service level if they improve their reverse SCM strategies. The authors (Hammant et al., 1999) did not focus on the automotive reman aspects. Ilgin and Gupta (2010), in a recent publication, reviewed over 540 publications addressing environmentally conscious manufacturing since 1998 and concluded that the research, to date mostly focused on operational and tactical issues and stressed the need for research on strategic analysis. In summary, the literature is sparse when it comes to integration of reman and reverse logistics issues in promoting sustainable SCM. Furthermore, there is no structured, strategic decision-making framework for aftermarket reman, in particular, for companies involved with OE production. The objective of our work is to close that gap by building the most relevant theories.

Carter and Rogers (2008) developed a conceptual theoretical framework for sustainable SCM from an extensive review of the literature by integrating four distinct theories – resource dependent theory, transaction cost economics, population ecology and the resource based view of the firm. The four theories, while originating from divergent disciplines, were selected for their synergy and completeness in addressing sustainable SCM: resource dependence from sociology and political science, transaction cost economics from economics, population ecology from biology and the resource based view from strategic management and theory of competitive advantage.

For these same reasons, we too build upon these four theories for the reman decision-making framework as follows: *Population ecology theory* supports a sustainability perspective that is paramount to our theoretical foundation for the RDMF framework; *Resource dependence and resource based theories* focus on resource acquisition that is crucial to aftermarket reman due to the dependency on used products (cores) and their acquisition; Finally, we used *transaction cost economics* theory because it can be used to focus on reman costs, a key driver for strategic reman decision-making by OE suppliers. These theories were then interconnected within the RDMF framework developed based upon the authors’ previous work (Subramoniam et al., 2009a) and prioritized in the current work as shown in Fig. 1.

In the context of sustainable SCM, the authors of this paper also view outsourcing as an opportunity and now discuss the theoretical aspects of outsourcing for aftermarket reman companies. Bolumole et al. (2007) developed a theoretical framework for outsourcing logistics and found that the effective exploitation of resources in the strategic decision-making process, not just resource availability, provides a significant competitive advantage. The authors

Theory \ Reman Factors	Financial	Reman design	Intellectual property	Product recovery value	Customer product specs	Disposal costs	Product lifecycle costs	Core Mgt.	Brand erosion	Green perception	Regional reman operation	Org. alignment	Govt. regulations
Transaction cost economics	x	x		x		x	x	x	x		x		
Resource based view			x					x		x	x	x	
Population ecology					x					x			x
Resource dependence view	x							x					

Fig. 1. Reman theory linked to strategic aftermarket reman factors. Reman strategic factors derived based on the authors’ work published in Subramoniam et al. (2009a).

(Bolumole et al., 2007) focused on transaction costs, resource based and network theories to analyze outsourcing. The network theory takes a broader approach to SCM by reviewing resource availability not just within an organization, but also throughout the whole supply chain with a focus upon value creation. We reviewed the network theory to analyze the outsourcing option available to the reman supply chain. We developed a strategic decision-making process for the OE companies and recommend outsourcing as an alternative if internal competencies cannot be developed. In doing so, we further expand the concept of sustainability from within the organization to the supply chain.

2.1. The population ecology perspective

The population ecology perspective emphasizes that limited environmental resources can constrain populations (Hannan and Freeman, 1977). This means that some populations, and organizations within populations, disappear and others survive (Hannan and Freeman, 1988) and that in order to survive, firms must control limited environmental resources. For automotive OE companies, this translates into energy and material savings from remanufacturing or reusing previously used products. In many cases, automotive suppliers are constrained by what the OE customers demand. Nevertheless, the products that are manufactured can be remanufactured to save energy and materials, especially if they are designed to be remanufactured.

The population ecology perspective also posits that organizations fail to adapt due to inertia. In our case for the automotive industry reman example, this is very true because the companies have, for a very long time, focused on a “new product” approach instead of a “reuse/reman” product thinking, at the strategic planning levels.

2.2. The resource dependence perspective

The resource dependence perspective proposes that organizational success and company survival occurs by maximizing power (Pfeffer and Salancik, 1978) through the acquisition of scarce and valuable resources (Pfeffer, 1981) in a sustainable and efficient manner. For the remanufacturing supply chain of OE suppliers, one of the key challenges is effective management of used products (or cores) within reverse logistics. This process is challenging for the OE suppliers who have to depend on outside brokers for their supply of used products or “cores”. These cores must be managed by the OE suppliers, in some cases, through vertical integration by using the defective products rejected from their OE manufacturing plants for remanufacturing. This is an efficient way to promote improved sustainability for the company or the supply chain, based upon remanufacturing defective products for service and aftermarket parts. This relationship between resource dependence and vertical coordination becomes even more important under conditions of uncertainty (Pfeffer, 1981), which is based on both dynamism and complexity (Duncan, 1972) in the supply chain. The uncertainty in core availability can negatively impact the aftermarket business if it is discovered during the implementation phase that cores are unavailable for parts with high volume demand.

2.3. Transaction cost economics

The transaction cost literature suggests that firms under conditions of uncertainty are more likely to vertically integrate, by creating bureaucracies or clans (Williamson, 1979; Penrose, 1959) or other, more vertically coordinated governance mechanisms (Williamson, 2008). These observations led Carter and Rogers

(2008) to posit that the firms that face uncertainty regarding key, external resources can improve their economic sustainability through vertical coordination. They continued with another principle, namely, that there is a positive relationship between vertical coordination and the interaction of uncertainty and resource dependence. In other words, companies can reduce uncertainty and their dependence on key resources by engaging in vertical coordination. In the current work, the OE suppliers can vertically integrate the core supply within their organization as discussed in Section 4.4. This will reduce the uncertainty of core availability and thereby, increase the economic viability of their aftermarket business.

2.4. The resource based view

Traditionally, the field of strategic management has been used to analyze an organization's external threats and opportunities (Ansoff, 1965; Porter, 1980; Porter and Kramer, 2002) with the belief that internal organizational resources are homogeneous and existing resource heterogeneity, within an industry, will be short-lived (Porter, 1980). The resource based view (Penrose, 1959; Rumelt, 1984; Wernerfelt, 1984) challenges these assumptions and posits that: Strategic resources within an industry may be heterogeneous across firms; these resources may not be mobile, and as a result the resource heterogeneity may be long lasting (Barney, 1991). Hence, the resource based view suggests that a firm may achieve economic sustainability by effectively employing its resources. Barney (1991, p.101) defined firm resources to include: [...] “all assets, capabilities, organizational processes, firm attributes, information, knowledge etc. controlled by a firm that enable the firm to conceive of and to implement strategies that improve its efficiency and effectiveness.” The information or knowledge resources are stored by organizations not only in their procedures and rules, but also in their less formal norms and social and communication patterns. These knowledge resources include training, experience, social relationships and insights of managers and workers. For the aftermarket remanufacturing business model, this could mean the ability of the OE Company to learn and to improve its business processes (Subramoniam et al., 2008, 2009b) that will improve its effectiveness and efficiency. Also, it could be the ability of the OE company to forge relationships with its suppliers and to promote environmentally and socially responsible practices, for example, use of recyclable packaging and developing minority suppliers, by sharing knowledge. These types of sustainability initiatives across the supply chain can result in a “Green” marketing image that can be “sold” to customers and consumers; this could help them to improve their economic and ecological business performance. These perspectives are in line with Carter and Rogers's (2008) proposition that supply chains, which integrate social and environmental resources and knowledge, may be more difficult to imitate, thereby resulting in their strengthened economic sustainability. In addition to creating a Green image, the OE company also needs to make reman products attractive and acceptable for the end consumers. The acceptability of reman products, from a consumer's perspective was analyzed by Michaud and Llerena (2006). They found that the consumer's willingness to return the products to close the loop depends, in part, on the information given by industrial actors to consumers. The increased willingness to return used products can be achieved by marketing the quality of reman products. For example, by comparing new and remanufactured products and by providing test data that proves remanufactured products to be as good as new ones. Further, end users of remanufactured products save money because of their lower cost (with respect to new products).

2.5. Outsourcing: a strategic reman process alternative

The theoretical aspects of outsourcing and logistics were analyzed by Bolumole et al. (2007). They identified three different theoretical perspectives: a) Resource based reasons, due to lack of internal resources, b) Network theory due to internal vs. external control and c) Transaction cost analysis based upon the potential to minimize costs that influence outsourcing decisions. The authors concluded that it is not merely the availability of resources that will result in a competitive advantage but also how these resources are exploited and embedded in the organization's strategic decision-making process. It is clear from Subramoniam et al.'s (2009a,b) experience and the case studies in the automotive industry that the OE automotive supplier companies have not exploited the resources available to them to increase reman throughput. If the OE supplier companies would like to externally expand their core resource acquisition, they could outsource the core acquisition process from external core brokers through well-established distribution focused, data-driven companies like Amazon.com.¹ The supply chain visibility from, for example, Amazon.com, can reduce the uncertainty in the reverse logistics process. It can also help to reduce inventory in the supply chain and can help build better forecasting models for OE suppliers. The OE automotive supplier companies can then focus on their core competency, to manufacture reman products with OE parts and to partner with a supply chain leader like Amazon.com, which can focus on its core competency; i.e., logistics with effective use of data from their information systems to coordinate the flow of cores and to distribute the remanufactured products to the end consumers. This process supports a network theory approach, where value creation through resource availability happens somewhere in the supply chain, thereby, enhancing their competitive advantage. The key drivers for selling reman products online were analyzed by Subramaniam and Subramanyam (2009) from an empirical analysis of various product categories on eBay. They identified that the seller's reputation to provide quality reman products has a significant impact on the buyer's decision for reman products. Furthermore, the online market place allows existing customers to provide feedback resulting in better decision-making for the potential buyer. Technology (i.e., the internet) is therefore, transforming innovation at its core, allowing companies to test new ideas at speeds and prices that were unimaginable even a decade ago.

The authors of this paper now discuss the theoretical aspects of decision-making and the different approaches to decision-making in the context of reman processes.

2.6. Decision theory

Decision theory is closely related to information processing theory, and is frequently represented by a series of mathematical models. Quantitative techniques are often used to review potential decision outcomes and potential solutions to problems. The most popular techniques are regression analyses, financial modeling, statistical simulations and optimization models (Meredith, 1993).

Decision theory practitioners perceive decision-making as a relatively straightforward and uncomplicated process, with solutions that occur in two types of basic categories; programmed or structured problems and those for non-programmed or unstructured problems. Programmed or structured problems are well defined, where the methods for evaluating options are explicit and little or no ambiguity exists during evaluation. Conversely,

problems, which do not fulfill those criteria, and are unique or are not of a routine nature, are categorized as non-programmed or unstructured. We now discuss the various approaches to decision-making and the characteristics of decision-makers before we choose the approach for the strategic RDMF for OE suppliers.

2.7. Approaches to decision-making

There are three different approaches to decision-making: normative, descriptive and the hybrid approach. Each is discussed in the following paragraphs.

2.7.1. The normative approach

The normative approach seeks an optimal solution to a well-structured problem. The methodology uses probabilistic methods or complex mathematical theory to solve the problems.

2.7.2. The descriptive approach

The descriptive approach is a behavioral approach with less emphasis on "what to do?" The heuristics (rules of thumb) approaches are used in seeking answers to unstructured problems.

2.7.3. The hybrid or prescriptive approach

The hybrid or prescriptive approach is a combination of the normative and descriptive ways to decision-making. The hybrid or prescriptive model suggests a good solution, not necessarily an optimal solution that way providing the decision-maker the support to make quick decisions.

Now we explore which of these approaches fits best within RDMF? Decision-makers often want to minimize risk with a "satisficing" choice behavior. They often look for "good enough" and not necessarily optimal solutions for unstructured problems. Humans tend to go with recurring patterns, not probabilities. Hence, the normative approach that requires the optimal solution is excluded as a potential strategic, decision-making solution for reman.

A descriptive model or approach uses a computer algorithm or program to perform the calculations associated with each alternative and describes a cause-effect relationship. The model will not provide a judgment of the desirability of the alternative. The judgment is left to the decision-maker. Some decision-making models go beyond the scope of identifying the alternatives for each decision node. They help the user determine the best choice among the alternatives. These models are called 'prescriptive' models. Prescriptive models leverage the decision-maker by evaluating the tradeoffs that are too complex or numerous for human judgment to comprehend. The authors of this paper use a prescriptive decision-making approach in their proposed RDMF framework that shows the different decision nodes, factors etc. in the reman decision-making process and the different alternatives for those nodes. A prescribed solution is provided to assist the strategic decision-maker to decide if s/he should or should not seek to launch a particular reman program.

3. Industry survey development and results

3.1. Survey background and previous work

A survey or questionnaire provides a snapshot of the current state of affairs in a given group or population at a certain time; researchers call this approach descriptive work. As a first step before we started our survey development, a thorough review of the literature was completed to determine if other researchers had done similar or related survey. Lund and Skeels (1983) identified product selection, marketing strategy, reman technology, financial

¹ Amazon.com is a global Internet retailer with several different product categories including automotive aftermarket parts.

aspects, organizational factors and legal considerations as issues to be considered for companies starting reman operations. They identified some unique issues for OEM's which should be considered to reman a particular product. They included issues such as: feedback of reliability and durability information of the OE product, 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. Hammond et al. (1998) discovered, in their interviews with remanufacturers, that many changes, such as mass customization have occurred in the automotive industry. The rapid changes in the automotive aftermarket industry were also analyzed by Subramoniam et al. (2008) in a paper that focused on mass customization and on the increasing role of the dealerships in the evolving aftermarket industry. Severengiz and Supasil (2008) investigated the automotive remanufacturing industry in Europe using a questionnaire survey. They identified collection of cores as the most complex of all reman processes, which also caused the highest number of problems. Nash et al. (2003), in their automotive aftermarket reman inventory management survey, found that aftermarket companies should improve data and analytical capabilities including 'Point-of-Sale' (POS) data, while sharing demand information across the supply chain. All of these surveys were primarily focused on the general remanufacturing aspects without specific focus on the OE suppliers that provide automotive reman parts within all three businesses (OE, OES and IAM).

3.2. Survey objectives and survey process development

The first step in our survey development was to clarify the objectives for performing the survey with the focus on the automotive OE suppliers involved in both OE production as well as reman production for the aftermarket. The next big concern was ensuring representativeness of the sample of people to be surveyed. Forty-four companies were identified to be active in this category (OE, OES and/or IAM) of the industry with support from the Automotive Parts Rebuilders Association (APRA) membership directory and Automotive Aftermarket Supplier Association (AASA). Additionally, the experience of the primary author of this paper with the automotive reman industry helped further develop the survey contact list. Then the challenge was to ensure that the survey was completed by the business unit managers or chief engineers, who had a sound understanding of their overall business. The next step was to keep the survey simple and easy for people to understand and answer. AASA was engaged as a partner to administer the survey because of their reputation and presence in the automotive aftermarket; consequently we expected the response rate would be higher with such an established partner. Another reason to co-work with AASA was because they had previously obtained good results in administering similar surveys with commercially available questionnaire software packages such as zoomerang (<http://en.wikipedia.org/wiki/Zoomerang.com>).

3.3. Survey questionnaire

The next step in the survey development process was the questionnaire. The first question screened the automotive OE reman suppliers based on their company's involvement in all the three business models (OE, OES and IAM). If the companies were not involved in the aftermarket, they were screened out of the survey. The next question focused on whether reman was considered during the early bidding process for the OE business. This question is critical because of the importance of considering reman in the early stages of the product life cycle or it becomes an afterthought with added difficulties to launch reman. The remaining set

of questions sought insights from the invited participants for each strategic planning factor identified from the literature review (Subramoniam et al., 2009a) as follows.

1. Does the strategic factor (for example, product's design) influence your decision to reman?
2. What is your company's capability in dealing with this strategic factor?

The first question confirmed the relative importance of the factor in the respondent's reman decision-making. If all the respondents answered "Yes" to the first question, then the percentage importance was 100%. Consequently, the reman factors were prioritized based on how many respondents from the 18 different companies thought that it was important. The second question to all the survey participants was to rank their company's capability (on a scale from 1 to 5) to deal with that factor. From the respondent's answers, a weighted sum of the capability was calculated by multiplying the weightage with the corresponding number of respondents. For example, if 3 people selected a capability rank of 1 (Low) and 1 rank of 2, 4 rank of 3, 8 rank of 4, 5 rank of 5 (High) then the total rank was $(3 \times 1) + (1 \times 2) + (4 \times 3) + (8 \times 4) + (5 \times 5) = 74$. The capability ranking presented in Fig. 2 was developed in that way for all the reman strategic factors. The weighted sum helped distribute the weightage based on the number of respondents. For example, more respondents for a certain rank meant a higher weighted sum for that rank.

3.4. Survey results

The survey results² showed that most of the strategic factors identified from the literature review (Subramoniam et al., 2009a) were important to the respondents in their reman decision-making. The response rate for our survey is not only dependent on how many people responded (25%), but also on how many companies participated (42%). Even though 71% of the respondents stated that they considered aftermarket early in the product life cycle process and 62% of them even considered reman, it is clear from the company capabilities for individual factors that all the strategic factors are not given proper consideration and/or the degree to which they were considered varied in reman decision-making (Fig. 2). Now we discuss and analyze a few key factors to show how the answers helped the authors to develop the current version of RDMF. If at least 50% of the survey respondents considered the factor important in reman decision-making, then the factor was included in the RDMF framework in Section 4.

3.4.1. Design for reman

Design for reman was a strategic factor that was selected by all respondents as an important factor in their decisions to reman. However, 33% of the respondents considered their company's capability to deal with this factor to be average or below average. This is in line with findings from previous surveys and studies (Ijomah, 2009), where design for reman was one of the important factors affecting reman. This finding stresses the need for better product design guidelines and engagement of product designers and company leaders in the product design process so as to ensure that the products are designed to be remanufactured.

² The complete survey results with the questionnaire is available from the primary author (subramoniamramesh@yahoo.com) on request. They were not included in the manuscript due to space constraints.

Survey Questions	% of survey respondents who said YES	Weighted sum of the response on the respondent's company capability (Bigger number = more company capability to handle the strategic factor)
Does your understanding of financial impact of reman influence your decision to reman?	100	90
Does a product's design, with respect to ease of manufacture, influence your decision to reman?	100	79
Does the need to protect the Intellectual Property of the product positively influence your decision to reman?	95	89
Does increased product recovery value positively influence your decision to reman?	86	84
Do OE customer product specifications and requirements with respect to reman, influence your decision to reman?	81	91
Does the increasing speed of technology change, and the resulting disposal costs, positively influence your decision to reman?	81	78
Does the need to have cores (or used parts) of high intrinsic value influence your decision to reman?	81	81
Does a product designed with consideration of product life cycle costs influence your decision to reman?	76	74
Does the process to recover new cores (reverse logistics) influence your decision to reman?	76	81
Does the outside reman competition and the resulting brand erosion positively influence your decision to reman?	71	78
Does a "green" perception of reman products, with respect to energy and environment; for example, influence your decision to reman?	67	81
Does the need for a well integrated organizational alignment between your OE and aftermarket divisions influence your decision to reman?	62	74
Does the need for upfront financial investment negatively influence your decision to reman?	57	78
Do current government regulations influence your decision to reman?	52	81
Does the availability of cheap new products from the low cost countries negatively influence your decision to reman?	48	69
Does the need for an international reman facility influence your decision to reman?	43	77
Do good buyback incentives or lease for OE parts influence your decision to reman?	29	70
Does the perception, or acceptance of reman products by the auto OEM's negatively influence your decision to reman?	19	87

Fig. 2. Industry Survey Results for Automotive Aftermarket Remanufacturing.

3.4.2. Intellectual property

Ninety-five percent of the respondents claimed that the need to protect the intellectual property (IP) rights of their product positively influenced their decisions to reman. Also, 76% of the participants believed that their companies were capable of dealing with this challenge. The response on capability is interesting since many companies continue to fight battles to protect their IP (Pagell et al., 2007) from overseas competitors. While competitors from developing countries have not yet heavily engaged in the reman business for US and European markets, as they expand their reman or cheaper new products (Cruickshank, 2006), they can pose a bigger threat by producing counterfeit parts; this can be serious if the developing countries have little or no government control on protection of IP.

3.4.3. OE product specifications

This factor received an 81% confirmation as a key factor that influences their decision to reman. Also 85% of the respondents thought that their companies were in a good position to address these challenges. The response on the capability merits further analysis. A majority of these companies are able to guide their OE customers towards a reman product specification. This can be true for established reman products like in automotive audio systems, whereas for many of the newer reman products (For example, automotive engine control module), companies will have to deal with the already established designs for OE products and will need to steer the OE customer to accept the new reman designs for service and aftermarket purposes.

3.4.4. Product life cycle

The consideration of product life cycle costs in product design considerations was considered important by 76% of the respondents, but their responses on their company capability in considering these costs for product design lagged (weighted rank of 74 in Fig. 2). The lack of product life cycle planning in the early stages of the aftermarket business will result in poor preparation/launch of reman products.

3.4.5. Core management

Core management was identified and confirmed as a major factor by 76% of the survey respondents. The capability ranking of the companies also was high (weighted rank of 81 in Fig. 2). Many previous studies and surveys (Daugherty et al., 2003; Hammond et al., 1998) have also confirmed this as a major factor.

3.4.6. Organizational alignment

The survey results showed that 62% of the participants identified the organizational alignment between the OE and aftermarket divisions as an important factor and as a major deficiency (weighted rank of 74) within their companies. If we integrate these results with those of the core management question, the supply chain integration issue becomes broader and more important to ensure the performance improvement that companies need for remanufacturing. Frohlich and Westbrook (2001) studied 322 manufacturers and found that the companies with the widest arc of integration with both suppliers and customers had the strongest association with performance improvement. The end consumer's willingness to return products is dependent on the information provided by industrial companies. In this context, Michaud and Llerena (2006) emphasize that when an OEM collects and successfully remanufactures its own products, a high willingness to return the products by the consumer can be expected. In contrast, a low willingness to return cores is seen if reman operations are done by an independent organization (not the OE supplier). This is due to the inability of or lack of will of the independent

remanufacturer to develop core return arrangements with the end consumer and the automotive dealerships.

The organizational alignment factor touches most of the strategic factors we considered in the current research. A highly integrated, well organized reman organization linked with both the OE and aftermarket divisions, will improve remanufacturing throughput significantly and will help the organization to gain the optimum economic and environmental benefit as well.

Overall, as shown in Fig. 2, the factors of design for reman, organizational alignment, high speed of technology change and the resulting increased disposal costs, product life cycle costs, upfront financial investment, product recovery value and brand erosion were selected by the majority of the respondents as important. They also indicated that their companies lacked capability in dealing with these aspects. These factors definitely need extra consideration in creating and implementing the RDMF framework.

4. The proposed reman decision-making framework (RDMF)

The proposed RDMF framework was developed, based on the survey rankings and also on the factors and capability importance derived from the data presented in Fig. 2. The framework was designed and tested in an action research format in order to address issues in automotive remanufacturing as the strategic planning process progresses within the corporation. It is important to realize that reman decision-making should occur early in the process within OE divisions after the company has developed its vision for sustainability. This is in line with the end-of-life priority lists stated by Graedel and Allenby (1995), namely:

- Reduce materials content, and if possible, replace products with service;
- Reuse components/refurbish assemblies, design products so that basic, common parts can be used as reman upgrades;
- Remanufacture;
- Recycle materials;
- Incinerate for energy, if that can be done safely;
- Dispose of as waste, if it is not harmful to the environment;

Once the product decision is made, there are several factors to be considered for a sustainable framework as proposed by the New Zealand Council of Sustainable Development (Business Guide, 2003). These factors include: product's impact on society and environment, sustainable product's performance and price compared to the original product, product availability, employment conditions and consumer awareness of the product impact on the environment. Along with these sustainability framework factors, the following reman decision-making factors need to be considered early in the conceptual development stage of the product.

4.1. Economic, environmental and social impact of reman

A reman effort within corporations should always be supported by a viable financial business case and hence in our framework, the first factor to be considered is financial viability. Also a Life Cycle Analysis (LCA) of the product at this stage can be beneficial from a reman standpoint. Kim et al. (2008), in their analysis of remanufactured automotive products found that the environmental benefits are very significant and are similar to the economic benefits. In their case study of automotive alternators, the authors (Kim et al., 2008) found that a remanufactured alternator uses less than 20% of the materials, 16% of the energy and releases 35% of the greenhouse gas emissions of those released in the process of producing a new product. A similar analyses conducted by Smith and Keolian (2004) using an LCA model, compared the economic

and environmental benefits of reman and new mid-sized automotive gasoline engine. The life cycle analyses showed that a remanufactured engine could be produced with 68–83% less energy-requirements and 73–87% less carbon dioxide emissions. Furthermore, their LCA study revealed significant reductions of other emissions as well, with 48–88% CO reductions, 72–85% nitrogen oxide reductions, 71–84% sulphur oxide reduction and 50–61% non-methane hydrocarbon reductions. The comparison of environmental burdens was accompanied by an economic survey of suppliers of new and remanufactured engines showing a price difference for the consumer between 30 and 53% lower for the remanufactured engine, with the greatest savings realized when the remanufactured engine is purchased directly from the remanufacturer. The social impacts should be assessed in the LCA if the study is to be complete, even though the current LCA tools are more focused on the measures (Hutchins and Sutherland, 2008) from an environmental impact (e.g. human health) as opposed to effects on culture and upon the society-at-large. The LCA can provide the OE supplier with important information to help her/him to select the right product(s) to reman. A good reman financial model that includes reman costs such as reverse logistics, core broker pricing etc. is a prerequisite for selecting suitable products for reman. If, on the other hand, if the product is not financially viable to reman, then it is important to understand the reason(s). There are several reasons a reman product can fail the business case, such as the high investment costs for establishing a reman reverse logistics network or the cost of the quality assurance test equipment or due to the fact that the product was not designed to be remanufactured. The OE supplier should take steps to work with other stakeholders to initiate the necessary changes so that the products are designed for remanufacturing. Also, consideration should be given to distribute the reverse logistics expenses among the other reman products in the future instead of putting all the reverse logistics costs on the first launched reman product. The same logic applies for test equipment as well. Another way to reduce cost is to order the reman test equipment together with the sister OE divisions so that economies of scale can be accomplished with better savings from test equipment suppliers. The advantage in analyzing the reman launch failure reasons at this stage is that many issues that prevent implementation of reman can be eliminated and successful launches will result with proper coordination among the multiple stakeholders.

4.2. Design for reman and product life cycle costs

The next important factor identified in the survey was design for remanufacturing. The OE suppliers were identified to be weak in their capabilities in launching and executing a design for reman initiative/process for their products. It is important to develop creative design solutions through efforts such as a design for remanufacturing workshop with all stakeholders, at an early planning stage. A cross-functional, cross-divisional, cross-company workshop that includes suppliers and OEM's can result in the identification of the major design shortcomings (preventing the business case for reman) and help to ensure that the potential solutions are incorporated early in the product design phases. If the OEM automakers have product design specifications that are not conducive to reman, such workshops should be used to identify the gaps and potential solutions so that the products are designed to be reman-friendly.

A motivational example can be the requirement by an OEM automaker to use a sealed engine control module that may make it infeasible to disassemble it or to use it as a remanufactured product. A cost-benefit analysis at this stage, with the OEM automaker will reveal the potential to design the product so that it can be

remanufactured; this will reduce costs in service and warranty at a later stage for the OEM automaker and for the IAM parts for the OE supplier. Furthermore, at this stage, the product should be designed with the product life cycle costs in mind. If the after-market division is separate from the OE division within the supplier organization, there is a high probability that such comparative product life cycle costs are not taken into consideration during the design stage. The product life cycle costs include service costs, aftermarket costs, disposal costs, recycling costs etc. If the product designer is aware of these costs in the design stage, the reduction of these costs can be another motivation for the designer to integrate design for reman at this phase of product development. The following guidelines should be used for a design for the environment (DfE)/reman program by the OE supplier (Sundin, 2004).

- Make sure that the products are designed so that they can be easily disassembled/separated for remanufacturing and can be easily and economically be remanufactured. Modular product designs with high recovery value as cores that can be easily replaced should be encouraged;
- Ensure that product-related environmental communication is accurate, relevant, informative and verifiable by proper use of labels, tags and logos. This will encourage responsible consumer behavior for returning the cores for reman;
- Avoid toxic or hazardous substances in materials or production processes;
- Design products that can be easily recycled;
- Encourage keeping the consumption of resources to a minimum. Do more with less; Design products that:
 - Avoid unnecessary components;
 - Minimize energy in production and use;
 - Encourage production and usage of renewable energy;

4.3. Intellectual property

The third important factor, identified from the survey are issues pertains to IP protection issues. If at this stage, the OE supplier finds that even if the IP rights are not important enough to be protected, that product may still be a viable reman product if it is financially viable and if it is properly designed for reman. But if the IP is important enough to be protected, it is an additional driver for the OE supplier to have that product remanufactured.

4.4. Product recovery value

The recovery value for the product is a crucial driving factor for recovering the cores. If the recovery value of the product is small, it is hard to justify remanufacturing it even if the product is designed for remanufacture. If there is not enough value in the cores, then the dealerships and other reman core brokers will not invest in the effort to recover the cores. The auto dealership will discard the product rather than store and recover the return core's charges³ from the OE supplier. The first step in the recovery process is to establish special incentives for dealerships to recover cores from the customers. The core charges should be high enough for recovery to be economically viable for all players in the chain. Commodity products with a lower recovery value have a higher chance of not being remanufactured. The recovery value can be increased by appropriate product design so that the base part assembly has more value than the component parts. In that way,

³ Remanufacturable returned parts can usually be redeemed for a portion of their original purchase price if the OE suppliers pay a core charge to their customers.

the assembly can be used to build multiple remanufactured products for the OE supplier, with minimal design changes for the base part. Another way to address this issue as mentioned in Section 2.2 is for the OE supplier to have the core supply coming from the OE manufacturing plants as rejects, scrap etc. This will allow the OE suppliers to control the core supply within the organization. This is particularly crucial for IAM when the cores for those products the OE supplier would like to release in the aftermarket are not available from the core brokers.

4.5. Product specifications from the OE customer

The product specifications from the OE customer may not support a remanufacturing process or there can be situations where the OE customer might be concerned about safety of the components and therefore, is not willing to reman that part. This kind of situation warrants a proactive approach from the OE supplier with real performance and safety data to provide well-documented evidence to the OE automaker that a remanufactured product will function as well as a new product. The economics of a remanufactured product are already proven. Hence, a little further push with proper test data (such as full life cycle tests comparing a remanufactured and a new product) may help to shift the OE customer towards a remanufactured product.

4.6. Product disposal costs

The product disposal costs will become a more important factor in the future as companies are more stringently controlled by governmental regulations such as “Extended Producer Responsibility (EPR)”, which are designed to force producers to take life cycle responsibility for their products. OE suppliers should become active in influencing the government to change restrictions or regulations that hinder or discourage reman (e.g. import restrictions for cores). They should co-work to launch reman programs by coordinating their efforts with other suppliers and by working with agencies like the Automotive Aftermarket Supplier Association and Original Equipment Supplier Association. These associations can provide inputs to government representatives on the need for changes in regulations that can help to green the economy and can help work with their government representatives to influence their foreign diplomats. Many nations are faced with dramatically increasing landfill charges, bans on certain kinds of industrial wastes and expanding EPR requirements. Therefore, OE suppliers will increasingly choose remanufacturing since it helps them to comply with the evolving regulatory pressures and also saves the value of the product and results in a more cost effective life cycle management of their products.

4.7. The core management process

An effective core management process is the backbone of all remanufacturing programs. At the strategic planning level, the availability of cores for the OES and IAM business models should be assessed with the OE production business team. A product exchange process is a typical way of making cores available for the OES team. In this process, the dealership collects the returned cores from the end consumer and sends them to the OE supplier. There is a core charge that the dealership and the customer will be paid by the OE supplier for returning the cores. As stated earlier, if the core charges are negligible compared to the cost of managing these cores, the percentage of cores returned will be low. On the other hand, for the IAM team, the OE supplier should decide which parts they are planning to launch in the IAM. Once that decision is made, preferably early in the process, the parts availability challenge can

be solved through an effective core broker relationship with the support of data-driven online technology companies. Another alternative is to make the cores available as rejected parts from the OE production plants. If for any reason, the core management process, cannot be handled by the OE supplier, the supplier should drop the reman program since a reman program will not succeed without an effective core management process.

4.8. Brand erosion

The automotive aftermarket program is driven globally by the brand name of the OE supplier (Subramoniam et al., 2009a). If the OE supplier is not providing these parts in the aftermarket, the business will attract outside competition (Ouchi, 1980). In that scenario, the products will be disassembled and remanufactured by an independent company. In this effort, the independent supplier may have to reverse engineer the product; this may result in the technology becoming available to outside manufacturers. This can be detrimental for the OE supplier for a technology-oriented product due to loss of competitive advantage. Additionally, due to global competition, counterfeit product manufacturers from emerging economies can remanufacture and sell the product with the supplier's brand name. A way to prevent or to reduce the resulting brand erosion is for the OE supplier to be involved in the reman business for the OES and IAM businesses and to thereby fight counterfeit products as a coordinated effort with other OE suppliers through independent agencies like the AASA and OESA.

4.9. Reman as a green initiative

In light of the fact that a remanufactured product is a greener product and might qualify for green tax credits and support from the government, if the reman program is not treated within the company under a broader sustainability or green initiative, it will be to the OE supplier's benefit to consider such an effort. If not, the reman effort will become an afterthought, resulting in reduced reman throughput and lower benefits (Subramoniam et al., 2009a; 2009b).

4.10. Local reman operation

A regional reman operation is necessary to support the local customers and to gain support from the local government to launch reman operations. The authors feel that the companies are in their early stages of globalizing reman (hence the low survey acceptance (43%) in Fig. 2) and the factor will gain prominence in the coming years. Many governments have policies that prevent shipping products from the outside to support local customers. Initially, to get started, a global company might decide to import the cores from the parent country to get the program launched. Once the program is launched, the local customers will provide the cores to support the local reman operation. This approach will reduce transportation costs for shipping cores globally and will reduce the lead-time required to provide reman products to customers. If the company assumes its Extended Producer Responsibilities (EPR) responsibilities seriously, it will make, provision of local jobs, an integral part of its business plan, thereby, emphasizing social issues central to a sustainable operation.

4.11. Organizational alignment between aftermarket and OE divisions

The organizational alignment between the OE high volume businesses and the aftermarket reman low volume businesses is an internal issue for the companies. It must be addressed first as soon

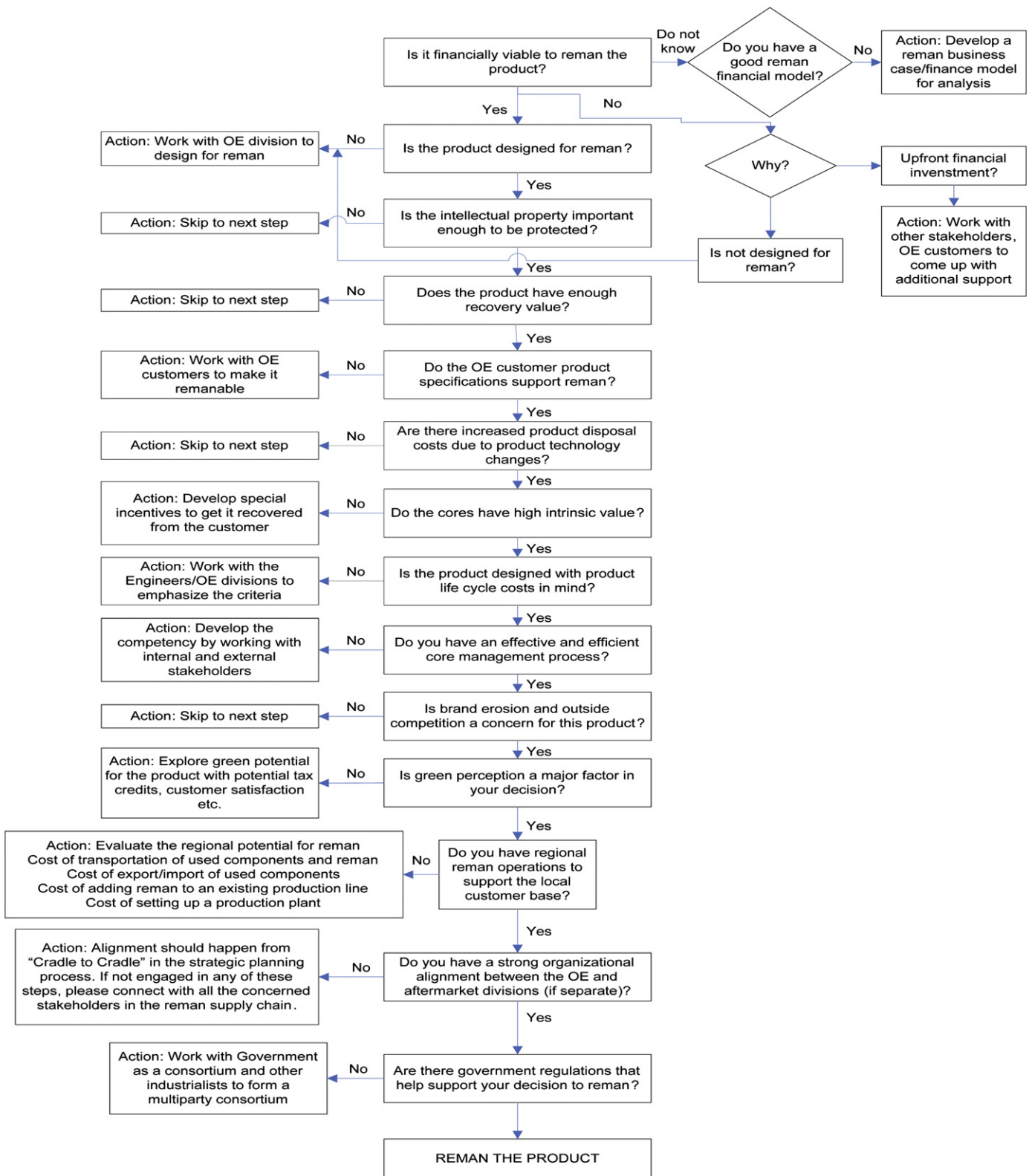


Fig. 3. Automotive Aftermarket Reman Decision-making Framework (RDMF).

as the company leaders decide to reman their products. In many cases, the aftermarket business is treated as a separate business model due to increased revenue and growth potential. The low volume mind set required for aftermarket part's management is different from a high volume production philosophy for the OE production team. The OE division leadership should assess and integrate the revenue potential for the aftermarket remanufactured products into the early phases of their planning process or they will not support the aftermarket division to implement proper reman programs. Once the internal stakeholders are in agreement with the reman business model, the external stakeholders should be integrated to support reman production. The high volume OE divisions will be reluctant to introduce the low volume business model for reman products into their current manufacturing plant. In order to be effective and efficient, if necessary, a low volume plant with its different service requirements should be separate from a high volume plant. Other aspects of alignment between the divisions are in the design for reman, information systems alignment to support reverse logistics, revenue potential and profit sharing.

4.12. Governmental regulations

Governmental regulations like EPR can be an important driver for reman decision-making since it can help company leaders to be motivated to implement projects faster than if there were no such regulatory pressures. For example, if a company is made responsible through governmental regulations for its products at the end of their life cycle, then it will be more advantageous for the company to do reman than to send the products to a landfill. The renewed energy from the new USA administration and support globally from other countries on environmental issues will result in tighter environmental regulations from the government.

5. How to use RDMF?

As a first step to use RDMF, the top management should be committed to implement reman and will work even better if it is integrated into the sustainability strategy for the company. The framework described in Fig. 3 should be reviewed by the business managers and/or Chief Engineers from both the aftermarket and OE divisions at the startup phase of product concept and through the phase of customer negotiations. This conceptual launch process should include the initial bidding proposal for the product with the OE customer, negotiations with the customer and finally the launch that will start product development. If the company feels comfortable, they can also add weightage⁴ for each of the factors and develop an overall number for reman decision-making. A similar decision-making framework was also implemented for a Tier 1 automotive supplier as a user-friendly software tool. The framework helped the executive team to make reman product selection decisions and to also review the reman execution gaps when the product is in the conceptual stage. The authors of this paper strongly feel that it is up to the companies (depending on their business strategy, capability, production locations, products and markets) to decide on any strategic factor weightage in using RDMF. Even if the companies lack the capability for a certain factor, the action items defined in the framework can be pursued by the

company and in that way they may more effectively proceed with reman.

Overall, we conclude this section with a motivation quote regarding RDMF from Dale Hostetler, a Reman Engineering Director (retired) of a major OEM supplier: "As such the RDMF framework is an effective checklist to assure that all pertinent factors have been considered before proceeding. Also, the field of factors seems to cover all the important areas of the financial impact; the environmental impacts; the reverse logistics dimensions, and; the organization's ability to access the technical information needed. I believe that each company can use the RDMF fundamental framework as a guide but develop their own RDMF based upon the idiosyncrasies of their products and business processes – which would be a significant compliment to their work."

6. Conclusions and next steps

An RDMF framework was developed based on thoroughly researched strategic factors for the automotive aftermarket reman industry. Also related reman theories were built to connect theory with practice. The industry survey helped the authors prioritize the factors and strengthen the framework. The authors believe that the framework in its current form provides valuable guidance for OE suppliers to make strategic decisions for reman products. These reman strategic decisions with a thorough consideration of carefully selected factors will help the OE companies to launch reman products effectively and efficiently. That way, RDMF will be a valuable contribution for the OE supplier companies, which are under recent intense environmental scrutiny already by the governments and the society-at-large (For example, British Petroleum for the gulf oil spill.). Future research will involve further validation of the RDMF framework by carefully selected reman specialists in diverse segments of the reman supply chain.

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⁴ The weightage for the strategic factors will be based on the importance of the factor to the OE supplier. For example, if intellectual property is important for a high technology product then that factor will have a higher weightage that will result in a higher overall ranking for the product to be remanufactured.

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