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Conditions of emergence of OEM's reverse supply chains

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Abstract

Although academic research and some industrial experiences show that a reverse supply chain (RSC) based on remanufacturing offers the possibility to transform the constraint of environmental regulations on product recovery into an opportunity for value creation, few companies have managed to set up their own RSCs. Five research propositions on the condition of emergence of RSCs follow from a literature review and are applied to a case study from a global player in the electrical and electronic equipment (EEE) industry. The findings support the importance of an integrated approach for the design and implementation of a RSC. This integrated approach responds to the traditional questions of OEMs, 'Why' set up a RSC?; 'What' main conditions must be taken into account in the three segments of a RSC (procurement, production, and distribution)?; and 'How' can these conditions be satisfied?

Keywords: Remanufacturing; Reverse supply chain; Conditions of emergence

Introduction

In some industries, the value created by the forward supply chain (FSC) can no longer ensure the firm's viability. Recently, some industrial sectors (e.g., the industry of photocopiers) have seen the emergence of a new form of value creation called the reverse supply chain (RSC). This new chain is intended to complement, not to replace, the chain of value creation initiated by the FSC. A RSC can be considered as an organizational innovation that enables the firm to have a double chain of value creation. The RSC can be defined as 'the series of activities required to retrieve a used product from a customer and either dispose of it or reuse it. Indeed, for a growing number of manufacturers in industries ranging from carpets to computers, reverse supply chains are becoming an essential part of business' [1].

With the enforcement of waste electrical and electronic equipment (WEEE) regulations in Europe, manufacturers of electronic and electrical products have become responsible for the recovery and recycling of their end-of-life products. To meet this statutory requirement, most manufacturers use the services of approved reverse logistics providers. Given the complexity and heterogeneity of the recovered flows, the recovery channels implemented by reverse logistics service providers are primarily recycling-oriented. Generally, these channels do not create economic value for original equipment manufacturers (OEMs) and represent an additional burden on industry. This is why OEMs prefer to outsource most of these channels. Unlike a recovery

channel based on recycling, a RSC creates tangible value for the company. Although academic research [2,3] and some industrial experiences (Xerox, IBM, etc.) show that RSC-oriented remanufacturing offers the possibility of transforming this extra burden into an opportunity for value creation, few OEMs have established their own RSCs. According to Hauser and Lund [4], among the 2,000 companies in the USA which claim to be 'remanufacturers', only 6% are OEMs. The remanufacturing industry is represented mainly by SMEs creating value by remanufacturing OEM products.

Some proactive companies have already managed to implement RSCs in an environment characterized by high uncertainty. Simply imitating these companies' models does not guarantee success for other companies [5]. However, most companies interested in creating RSCs tend to copy existing models in their industry. DiMaggio and Powell [6] assume that the ubiquity of certain structures is rather due to the universality of mimetic processes than to any concrete evidence showing the effectiveness of the adopted models.

This tendency to copy existing RSCs is due to the lack of models adopting a holistic vision (systemic) that take into account all aspects of the RSC [7-9]. The remanufacturing industry lacks a comprehensive framework that includes all the major strategic factors necessary for making effective remanufacturing decisions earlier in the conceptual stage of product development [10,11]. Most research focuses on treating some particular problem of the RSC and trying to make local optimizations (e.g., inventory management, production planning) [7]. Given their lack of knowledge about RSC design, managers first need general models that demonstrate and explain the conditions to be met at the first stage of RSC design. These conditions represent the common basis that underlies all RSCs; elements that differentiate RSCs, such as the model of inventory management, are involved in the second stage of the design process (detailed design).

Thus, the conditions of RSC emergence must be considered right from the first phase of design (foundations of the RSC). Satisfying these conditions can reduce the uncertainty and risk perceived by management [12], thus strengthening management decisions to invest in establishing a RSC. To date, few contributions have investigated the strategic conditions of development and implementation of RSCs [13,14]. The aim of this paper is to explore the strategic conditions of emergence of OEM's RSCs through a literature review and to assess these conditions by using a case study in the context of an EEE manufacture.

The paper is structured into three parts. In the first part, the emergence of a RSC is defined and five research propositions related to the proposed conditions of emergence of a RSC are derived from a literature review. Next, a case study from a global EEE company is analyzed to explore the research propositions in practice. Finally, in the third part, the revised theoretical propositions are incorporated in a proposed model.

Literature

Literature is relating to our research focuses on identifying the main conditions of RSC emergence. These conditions are classified into three categories: the 'Whys', the 'Whats', and the 'Hows', representing respectively the traditional questions asked by OEMs interested in a RSC project: Why set up a RSC?; What main conditions must be taken

into account in the three segments of a RSC (procurement, production, and distribution)?; and How can these conditions be satisfied?

The 'Whys'

With the emergence of sustainable development and life cycle management, the notion of sustainability is attracting more and more companies. Every viable system should be designed bearing in mind its economic, environmental, and social dimensions. Several studies have explored these three dimensions in the context of remanufacturing [15,16]. In the following paragraphs, we will examine the main economic, environmental, and social reasons that drive companies to set up RSCs.

Economic drivers

Originally, companies' interest in remanufacturing stemmed from economic motivations. Guide and Van Wassenhove [7] state that the remanufacturing industry in the USA is well organized and economically profitable; its development is based on profit rather than environmental concerns. Our literature analysis revealed the economic incentives shown in Table 1.

Environmental drivers

Several industrial experiences (Xerox, Caterpillar, etc.) showed that firms' environmental responsibility is not inconsistent with the creation of economic value. Besides bringing economic benefits, remanufacturing generates an environmental gain greater than that generated by recycling [15,24]. Remanufacturing appears to be one of the best solutions for combining corporate environmental responsibility with profitability [3]. The main environmental motivations appearing in the literature are synthesized in Table 2.

Social drivers

In the academic field, few studies have examined the social drivers regarding remanufacturing [15]. In the practical field, several mentions of the social advantages of remanufacturing could be found. The example of the remanufacturing industry in the USA shows that products are recovered, remanufactured, and reconsumed within the USA. Simply entering the words 'remanufacturing locally' in an Internet search engine reveals how widespread this social dimension is in the remanufacturing industry. In the USA, this industry supports the idea that local remanufacturing is cheaper than exporting remanufacturing to a low-cost country in view of the logistics costs involved. Remanufacturing may also prompt some companies to relocate their production activities to the country of origin (i.e., the USA) if they can capitalize on the synergy between the production of new products and remanufacturing. Our analysis of the literature and some remanufacturers' websites shows that the main social motivations are as follows:

Table 1 The main economic incentives

Common focus	Main economic incentives	Sources
Economic incentives for remanufacturing and RSC	Cost reduction	[7,13,15,17-23]
	Increased profit margin	
	Acquisition of a green image	
	Imitation of green competitors	
	Improved market value	
	Control of the secondary market	

Table 2 The main environmental incentives

Common focus	Main environmental incentives	Sources
Environmental incentives to remanufacturing and RSC	Compliance with environmental regulations	[3,7,13-15,17-24]
	Anticipation of changes in regulation	
	Reducing the environmental impact of product throughout its life cycle	

- Employment creation
- Saving local jobs
- Relocation of production to countries of origin
- Access of low-income households to low-cost products

To summarize, the existing bodies of knowledge identified in the literature review suggest that the emergence of RSCs has various economic, environmental, and social drivers. Thus, we can formally state the following proposition:

Proposition 1: The emergence of a RSC is conditioned by the fulfillment of sufficient economic, environmental, and social gains for the OEM.

This proposition is a combination of the three following sub-propositions:

Proposition 1-a: A RSC emerges if remanufacturing promises to generate satisfactory economic gain.
Proposition 1-b: A RSC emerges if remanufacturing promises to generate satisfactory environmental gain.
Proposition 1-c: A RSC emerges if the remanufacturing promises to generate satisfactory social gain.

The 'Whats'

Having addressed the first question: 'why' designing a RSC? we now turn to a second level in which the firm raises the question of what to consider in designing a RSC. By analogy with the FSC, a RSC comprises three main processes: procurement, production, and distribution. Considering that these three components give interested managers a holistic view of a RSC project, the following sub-sections discuss the main conditions to be satisfied in each RSC component.

Distribution chain: market orientation of remanufacturing

For Singh [25], market orientation represents the set of organizational activities coordinated to generate customer satisfaction through high-performance products, while remaining competitive in the market. If market reaction cannot be ignored when introducing a new product, it is essential to take this dimension into account when introducing a remanufactured product [26]. Indeed, the response to the customer expectations regarding remanufactured products is a strategic decision that requires managers to understand the market, the customers, and the potential influence of remanufacturing on strategy and the firm's distinctive competencies [13]. Among the influences on business strategy, introducing remanufactured products could involve the risk of market

cannibalization [8]. This is why in addressing the area of market orientation in the context of remanufacturing, we focus primarily on customer needs and the risk of cannibalization.

Customer needs Customers are the source of the product's returns, and at the same time, they are the potential buyers of remanufactured products. Guide and Van Wassenhove [1] state that the expectations of customers who buy remanufactured products are different from those of customers who buy new products. Thus, a company interested in remanufacturing must first identify its customers' needs. Our literature review identifies four factors influencing the customer decision when buying a remanufactured product:

a. Price of remanufactured products
   Consumers typically value remanufactured products less than the corresponding new products [27]. Debo et al. [17] have explored the impact of customers' profiles on the potential of remanufacturing. Based on empirical findings, they showed that customers value remanufactured goods less than new products and they are therefore not willing to pay the same price for remanufactured products. This difference between the price of new and remanufactured products is due to the uncertainty associated with the quality of remanufactured products; it is probably also due to customers' lack of knowledge about remanufacturing [26].
b. Quality of remanufactured products
   Remanufacturing is often confused with recycling [21,28]. Given customers' lack of knowledge concerning the concept of remanufacturing, the image of its quality is relatively impacted by the image of recycling. Bronstad and Evans-Correia [29] mention that a major barrier in the business of recycled materials is the poor perception of quality. So, to be considered as remanufactured, products must meet the same standards of quality as new products [13]. To exploit this quality image, OEMs must invest in marketing to convince customers that the quality of remanufactured products and new products is similar [30]. Customers who purchase remanufactured products because of this argument will be particularly demanding of product quality.
c. Environmental impact of remanufactured products
   Environmental aspects are an added aspect of customer needs. However, this need is not directly expressed by customers [31], may not be 'what they really want.' When the environmental aspects cause a price increase for the customer, they often constitute an obstacle to the act of purchase [31]. However, this problem does not arise in the context of remanufacturing because remanufactured products are generally cheaper than new ones. Furthermore, the 'green' customer segment clearly expresses environmental needs and favors the purchase of remanufactured products over new ones [32].
d. Upgradability of remanufactured products
   Upgradability is the updating of remanufactured product functions to the current level of technology. Umeda et al. [33] classify the reasons why consumers reject products into two categories. The first is 'physical obsolescence' of the product (performance, scratches, etc.), and the second is 'value obsolescence', meaning the obsolescence of product functionality. For example, many computers and cell phones are discarded due to obsolescence of their functional value. The upgradability of product features in order to meet new functional expectations may extend product lifetime [28].

Market cannibalization by remanufacturing The interrelationship between the demands on two products can be described as independent, complementary, or substitutable. In the case of substitution or cannibalization, reducing the price of product 'A' results in a reduction in quantity demanded for product 'B' [34].

Despite some company managers' interest in remanufacturing, they often find their efforts hampered internally because of fears of cannibalization of the market for new products [26]. Many managers expressed that market cannibalization is a real obstacle for remanufacturing projects [8].

Based on the literature review, the following proposition regarding the market orientation of remanufacturing is suggested.

Proposition 2: The emergence of a viable RSC starts with a market orientation of remanufacturing.

This proposition is a combination of the two following sub-propositions:

Proposition 2-a: To ensure customer purchase of remanufactured products, the following needs should be satisfied:

- *A lower price than the new product*
- *A lower environmental impact than the new product*
- *A quality equal to that of the new product*
- *Upgradability to new product technology level*

Proposition 2-b: Remanufacturing should avoid the market cannibalization of new products.

Production chain: design for remanufacturing

The purpose of remanufacturing is to bring used products to quality standards equivalent to those of new products. Used products are disassembled and inspected thoroughly to replace obsolete or faulty modules [30]. The remanufacturing is organized as an industrial process in order to achieve the benefits of mass production [35]. To facilitate the production process and to ensure high quality, products must be designed following the standards of design for remanufacturing. This design facilitates the remanufacturing process (inspection, cleaning, disassembly, etc.) [21,28]. A better design for remanufacturing also increases the economic and environmental benefits that can be obtained from the remanufacturing industry [28]. Thus, the following proposition can be stated:

Proposition 3: The emergence of a viable RSC is dependent on a product design facilitating remanufacturing.

Procurement chain: the uncertainties

The particular feature of the RSC is that it has two sources of supply. The first source is the supply of new non-reusable modules. This is handled in much the same way as the supply of modules for new products. The second source is the supply of used modules recovered from end-of-life products. This second source is referred to in the literature as 'reverse logistics network'. A reverse logistics network is how products are collected from the end user and returned to a facility for repair, remanufacturing, or

recycling [36]. A large portion of reverse logistics is concerned with core acquisition management. This area is responsible for core acquisition and ensuring an adequate supply of cores for remanufacturing [36]. This paper is particularly interested in core acquisition because it is the weakest link in the procurement chain.

The procurement chain of used modules is marked by high uncertainty about time, quality, and quantity of product returns [21,37]. In traditional production-distribution systems, supply is an endogenous variable in the sense that timing, quality, and quantity of inputs are controlled according to the system requirements. In contrast, supply is an exogenous variable in product recovery systems and it is difficult to control [38]. Therefore, the following proposition can be suggested:

Proposition 4: The emergence of a viable RSC is conditioned by the reduction of uncertainties concerning time, quality, and quantity in the procurement chain.

The 'Hows'

Pfeffer and Salancik [39] argue that with increased resource dependence, firms tend to increase vertical coordination. In the case of higher uncertainty, firms try to increase the level of vertical coordination between the focal firm and its partners [40]. In the context of RSCs, Carter and Ellram [9] emphasize that a high level of vertical coordination with customers and suppliers can lead to heightened adoption of new technologies, which also includes the adoption of reverse logistics.

Integrating internal and external supply chain actors into RSC design is a key factor if a RSC is to emerge. Genchev's study [41] about a large computer wholesale company shows a general change in perspective regarding the development of reverse logistics programs and emphasizes the importance of integrating the different stakeholders into the RSC design process. This section discusses how it is essential to coordinate decisions among actors of both internal and external supply chains to satisfy the 'whats' in the various RSC components.

Distribution chain: coordinating for better market orientation

As it was seen previously, the market orientation of remanufacturing consists of meeting customer needs and reducing the risk of cannibalization.

Coordination to satisfy customer needs In order to avoid product market failure, any design process should begin by defining customer expectations. The customer's voice defines the whole of the subsequent process [42]. RSC design must also comply with this logic starting by defining customer needs; indeed, all stakeholder decisions must focus on meeting those needs.

In order to favor purchasing of remanufactured products over new products, marketing teams must assess the conditions imposed by customers, namely price, quality, environmental impact, and upgradability. These conditions should be integrated into both product and RSC designs. For example, with regard to quality (it must be equivalent to a new product), designers should focus on product quality as well as the whole process of reverse logistics. In addition, the design team must identify the interactions among all the design parameters. Identifying these interactions shows how product design affects RSC design and vice versa [43-45].

Coordination to avoid market cannibalization At the launch of the platform of used goods in 2001, Amazon CEO Jeff Bezos said that he was 'pleased with the start' of the used product initiative and added that 'sellers love the platform'. Bezos said that he was not worried that Amazon's used business would hurt sales of new products (although the company said the slowing sales growth was due in part to sales of used products that are not recorded as sales; Amazon only takes a commission) [46].

To reduce the effect of market cannibalization, it is essential to coordinate the decisions of internal and external stakeholders. Concerning external actors of the supply chain, marketing must coordinate with distributors to develop a common strategy to promote remanufactured products. In some cases, if the profit margin from the sale of remanufactured products is high enough, retailers can promote the sale of remanufactured products over the sale of new ones [47]. Concerning internal actors, in companies where the production operations of new and remanufactured products are managed by two different divisions, the performance of each division is generally evaluated independently [27]. In such cases, internal coordination is essential in order to establish a strategy for allocating costs and benefits between the two divisions [27].

Production chain: coordination for better design for remanufacturing

To facilitate the process of remanufacturing (inspection, sorting, disassembly, etc.), products must be designed according to the standards of design for remanufacturing. Better design for remanufacturing increases the economic and environmental benefits that can be obtained from remanufacturing [28].

Redesigning products to comply with the standards of design for remanufacturing can influence other design parameters. Indeed, changing product design can affect production costs, environmental impact, quality, and modularity. According to Toktay and Wei [27], design for remanufacturing can result in higher production costs for new products; therefore, the additional production costs should be allocated to the cost of remanufacturing. Moreover, modifying the modularity of the product may change the modularity of the supply chain [48]. Thus, better design for remanufacturing requires the coordination of actors' decisions to take into account various issues related to any changes in product design

Procurement chain: coordination to reduce uncertainty

Because of uncertainties in the procurement chain, it is difficult to plan production and predict the amount of products that can be remanufactured. Uncertainty about the quantities to be 'remanufactured' is mainly due to two factors: firstly, uncertainty as to the time of returns and secondly, uncertainty about the quality of recovered products [49]. These two variables specific to the remanufacturing context can be added to other variables defining the quantity to be produced in a conventional production system, namely the quantity of supply (quantity of returns) and the quantity of demand. Figure 1 shows the interrelationships among different variables that define the quantity to be remanufactured.

Controlling uncertainty about the quantity to be remanufactured depends on controlling uncertainty about related variables upstream. It is possible to control these variables if decisions made by supply chain actors are better coordinated. For example, the development of options for acquiring products from customers (leasing, buyback, acquisition premiums, etc.) can give more predictable information about the time and quantity of returns; similarly, communicating market forecasts to the production

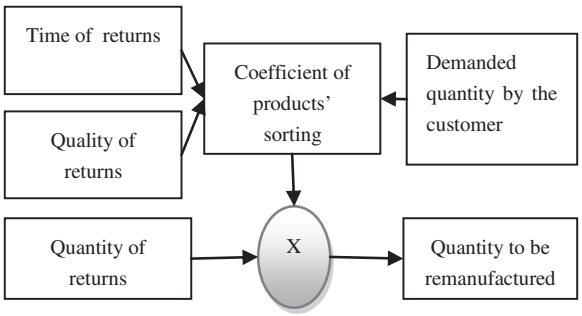

Figure 1 Variables determining the quantity of remanufactured products.

department improves forecasting of quantities demanded. Thus, we can formally state the following proposition:

Proposition 5: The emergence of a viable RSC involves coordinating the decisions of internal and external supply chain actors around market orientation of remanufacturing, design for remanufacturing, and reducing uncertainties in the procurement chain.

The case study

Case methodology

The five propositions were explored in a single case study of a global EEE company. The choice of this case is valid given that the company met the selection criteria derived from the research propositions [50]. Firstly, it was predisposed to set up a RSC for remanufacturing its end-of-life products. Secondly, access to the company enabled us to explore the RSC from a cross-functional perspective using key informants; this factor also supports construct validity [51]. Thirdly, the focus of the case study was restricted to the French market which is clearly driven by a leasing business model favorable for remanufacturing [11].

Given that the main purpose of our own study is to explain a hitherto unstudied phenomenon and possibly to develop theoretical propositions [52], this study can be considered as inductive research. A strong advantage of the case study method is that we can investigate the conditions of emergence of a RSC without removing it from its social 'real life' context [53]. Furthermore, this methodological choice allowed us to access critical business data such as bills of materials and production costs.

Data collection

The case study presented in this paper is part of a wider research project which aimed at developing a methodology for designing remanufacturing systems by combining eco-design and RSC. This case study is about a French producer of EEE machines interested in remanufacturing the company's end-of-life products. In view of data confidentiality, we will call this company 'Alpha'. The company produces electrical and electronic equipment for professional use and is ranked second internationally in its field. Its products are subject to WEEE regulation on end-of-life product recovery. The object of our intervention in this company was to transform an existing recovery channel of products at end of lease (Figure 2), qualified as partially industrial, to a RSC based on an optimized industrial process. This research comprised two main steps: the first was to collect data to analyze

and understand the existing situation and the second was to co-design the new remanufacturing system in collaboration with managers.

Given the exploratory nature of our research, the focus was on the collection of qualitative data that was highly relevant to our research subject. Regarding the study population, the sample was limited to key stakeholders involved in the design of the RSC. These belong to both internal and external supply chains of the company.

Six semi-structured interviews were conducted with heads of various departments inside the company involved in the remanufacturing project, two non-structured interviews with the providers of collection and recycling services, and several non-structured interviews with the quality, health, safety, and environment (QHSE) and eco-design managers who were our two main contacts within the company (Table 3). The questions in the interview guide were adapted to the function of each interviewee. No phone interviews were held. We also held six multidisciplinary meetings with the heads of the department involved in the remanufacturing project (Table 3). This specific study focuses on a single instrumental case [54]. These six meetings were organized to facilitate the investigation of the parameters to be taken into account in the RSC design and to present the progress of the project. Data collection of multidisciplinary meetings was carried out over 1 year.

Other secondary sources of data such as field observations and internal company documents were also used. The company agreed to make available many sources of data on the condition of strict confidentiality. All interviews and group meetings were recorded and transcribed. Coding and content analysis were conducted using NVivo 8 software. The plan for case study follows the suggested guidelines developed by Ellram

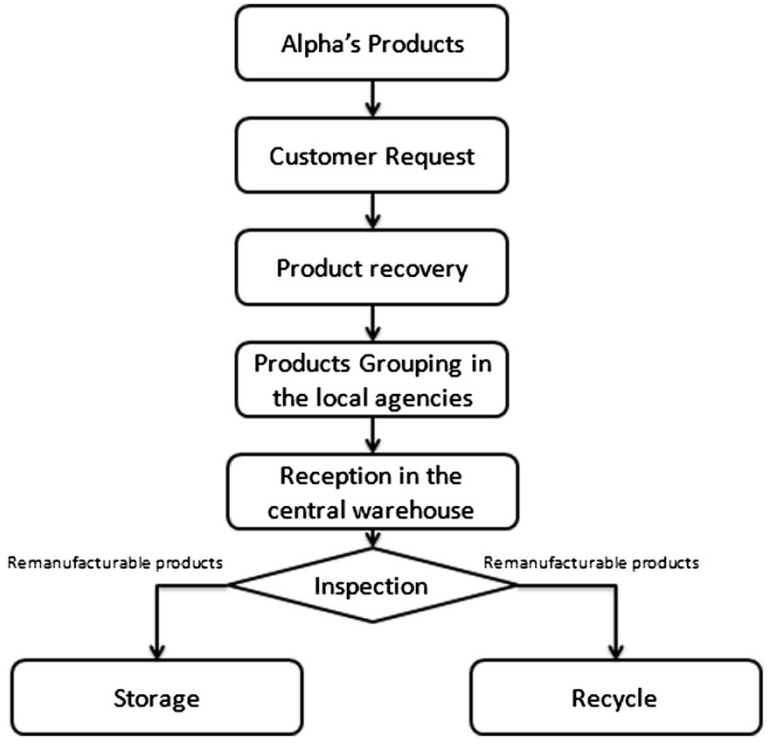

Figure 2 Alpha existing recovery channel.

Table 3 Detail of interviews and multidisciplinary meetings

	Function	Mission	Interview type	Interview duration	Participated in the 6 meetings
Internal supply chain	Marketing	Director	Semi-structured	1 h	Yes
	Production	Director	Semi-structured	1 h	Yes
	Supply chain	Director	Semi-structured	1 h	Yes
	R&D	Director	Semi-structured	1 h	Yes
	Procurement	Top manager	Semi-structured	1 h	
	Methods	Top manager	Semi-structured	1 h	Yes
	QHSE	Top manager	Non-structured	Several	Yes
	Eco-design	Top manager	Non-structured	Several	Yes
External supply chain	Collection provider	QHSE Director	Non-structured	2 h	
	Recycling provider	Top manager	Non-structured	2 h	

[51], and a case study research protocol is listed in the Appendix. The details of the research protocol are available from the authors upon request.

Findings

The results are now discussed in two sections: firstly, the role of RSC in the business of this company and secondly, a summary analyzing the case and comparing the findings with the research propositions.

The role of the RSC in the company business

Alpha's willingness to address the RSC competence stemmed from an acute awareness of current problems with managing product end-of-life. Even as a global player present all over the world, the company saw the French market unequivocally as highly attractive and critical for successful further expansion into European markets. The company had experienced strong growth in Europe seen in the high performance of European subsidiaries, the rise of leasing services, and the acquisition of distributors in Switzerland, Sweden, Norway, and Germany. Nevertheless, despite the strategic importance of the European market, customer requirements were beginning to change more rapidly, competition was fluid, and environmental regulations were becoming more stringent. The main strategic objective was thus to transform these constraints into a competitive advantage through remanufacturing. This involves managing two distinct but related processes: 'manufacturing' new products and 'remanufacturing' end-of-life products. Multidisciplinary meetings enabled us to identify the salient issues concerning remanufacturing. Interestingly, the problems were located throughout the whole of the RSC, from product recovery to redistribution. This is a good illustration of the notion of systemic approach to RSC design.

A common problem across the RSC was the need for a disciplined process. An in-depth analysis revealed bottlenecks within the current cross-functional processes. There is a

time-consuming and cumbersome company-wide process for the recovery of end-of-lease products. This process took more than 12 weeks overall. The two most time-consuming activities were company agents' recovery of products (4 weeks) and storage in local agencies before shipping to the central warehouse (8 weeks). On the marketing side, knowledge about customer needs and buying behaviors was still patchy. Marketers were overwhelmed by the specifics of the remanufacturing market, starting from a highly active secondary market to tightly controlled sales channels. Furthermore, Alpha managers stressed that remanufacturing parameters should be integrated earlier in the product design process. Everyone agreed that in order to streamline the remanufacturing process, the commitment of all functions to reduce the time-sensitive steps was essential.

Case analysis

The purpose of the case study was to explore in practice the five propositions derived from the literature review.

Regarding the first proposition, the findings from Alpha show that motivations for developing a RSC are mainly economic and environmental. At the time of the study, Alpha's economic targets were, respectively, to reduce manufacturing costs, to increase profit margin, to access new market segments, and to imitate competitors engaged in remanufacturing. Alpha's managers were confident that they felt comfortable that their RSC approach would support the achievement of these objectives. Furthermore, our findings reveal that acquiring a green image and controlling the secondary market appear not to be priorities for the company. Regarding the environmental drivers, complying with regulatory requirements and reducing products' environmental impact seem to be very important because they contribute to improve perceived customer value. The results also highlight the strong correlation between environmental and economic drivers.

Proposition 2 states that the emergence of a viable reverse supply chain starts with a market orientation of remanufacturing. The case study shows that market orientation is not only supported by the RSC but can also trigger the development of RSC competence. As with many companies today, satisfying customer needs is a strategic priority for Alpha. The analysis focused on which needs had to be satisfied: Alpha should remanufacture products priced lower than new products, with a quality equivalent to new products and upgradability to new product levels of technology; this is particularly true for software. The variable concerning environmental impact was not been verified. Alpha managers think that a big decrease in price could have a negative effect on customers' perceived quality of the remanufactured product. With regard to market cannibalization, data analyses show this risk as a major factor blocking the development of remanufacturing. Discourse analysis allowed us to classify market cannibalization into three categories, namely market cannibalization of new products by remanufactured ones of the same generation, market cannibalization of new products by the remanufactured ones of an older generation, and market cannibalization by competitors. The first and second categories are cannibalizations that are ‘negative’ for the company, while the third is ‘positive’. Managers' fear is mainly related to negative cannibalization. Alpha managers think that this negative cannibalization could be avoided by selling remanufactured products at the same price as new ones.

Regarding proposition 3, results show that one of the key points of the RSC project is to integrate the principles of ‘design for remanufacturing’ into product design in order to obtain a ‘remanufacturable’ product. Indeed, design for remanufacturing should

facilitate the remanufacturing process (disassembly, cleaning, etc.) in order to reduce costs and increase the quality of the treatment process. A modular design appears to be an encouraging route to achieving this end.

The results related to Proposition 4 show that managers perceive the uncertainties about time, quality, and quantity of return flows as a real constraint. However, they do not consider this constraint as a factor that might block the development of Alpha's remanufacturing program. There are two main reasons for this: first, there is a considerable stock of end-of-lease machines available in the company's central warehouse. Second, the company's business model is based on a leasing system allowing some control over the time, quality, and quantity of returns. In contrast, findings highlight a new uncertainty: that of the cost of remanufacturing as an obstacle to implementing the RSC. In fact, managers attach great importance to assessments of economic gain of remanufacturing compared to the production of new products. They argue that traditional accounting methods are unsuited to carrying out such evaluations. This means that new accounting methods need to be developed if possible gains generated by remanufacturing are to be demonstrated.

Regarding Proposition 5 which covers the coordination of decisions, our interpretation of managers' perceptions confirms the importance of coordinated decision making to give remanufacturing a market orientation while integrating the principles of design for remanufacturing into product design and reducing uncertainties in the procurement chain. Furthermore, our results highlight the emergence of two moderating variables for the emergence of the RSC. The first is a business model that offers a global concept, taking into account the main aspects of the remanufacturing system and demonstrating its viability. The second is overcoming the constraints imposed by the decentralized company structure which is not favorable to coordination. This can be done by appointing a project manager with sufficient authority to deploy the strategy of remanufacturing throughout the company.

Summary - towards a model of RSC design

On the basis of the propositions derived from the literature review and the case study findings, the theoretical propositions are revised for further research and combined into a model that integrates the conditions for RSC emergence (see Figure 3).

P 1': The emergence of a reverse supply chain is contingent on a satisfactory combination of economic and environmental benefits derived from remanufacturing.

P 1-a': The reverse supply chain emerges if the remanufacturing promises to generate a satisfactory economic gain.

P 1-b': The reverse supply chain emerges if the remanufacturing promises to generate a satisfactory environmental gain.

P 2': The emergence of a viable reverse supply chain starts with a market orientation and the avoidance of negative market cannibalization.

2-a': To ensure that customers purchase remanufactured products, the latter must meet customer needs according the following criteria: priced lower than the new product, quality equivalent to the new product, and upgradability to the level of technology of the new product.

P 2-b': The remanufactured products should avoid negative market cannibalization.

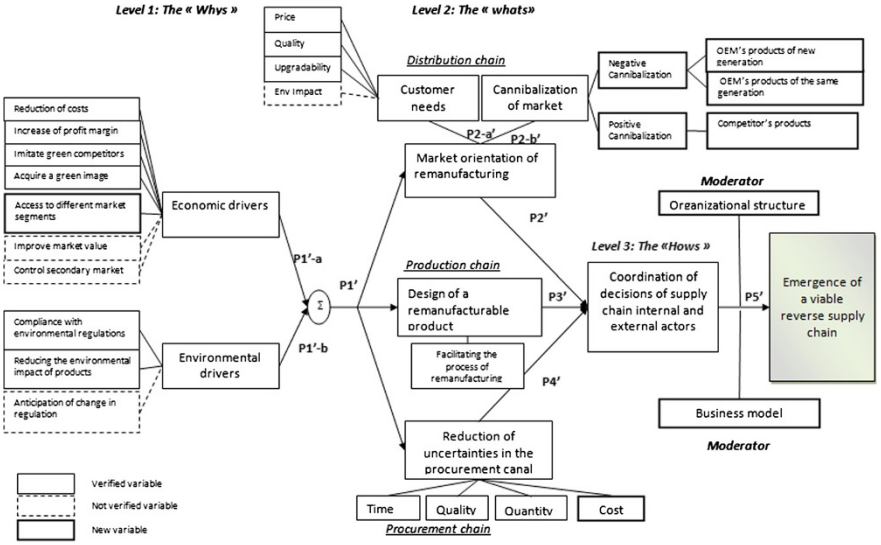

Figure 3 General model of emergence of a RSC.

P 3': The emergence of a viable reverse supply chain is dependent on a product design facilitating remanufacturing.
P 4': The emergence of a viable reverse supply chain is conditioned by the reduction of uncertainties about time, quality, quantity, and cost in the procurement chain.
P 5': The emergence of a viable RSC involves coordinating decisions of internal and external supply chain actors around a market orientation of remanufacturing, a design for remanufacturing, and the reduction of uncertainties in the procurement chain.

Conclusion

The constraints imposed by the business environment are increasingly pushing the emergence of RSCs. An integrated approach (as opposed to a fragmented approach) to the design and implementation of RSC is essential [37,45]. According to Stock [55], this integrated approach should follow flow mapping in the RSC. This is why we followed the RSC from product recovery to product reintroduction on the market in order to identify the key strategic conditions for RSC emergence.

Our case study followed the process of a company attempting to implement a RSC project. This case study allowed us to experience the design of the RSC as part of the project team. It demonstrates that setting up a RSC requires a proactive approach that necessitates organizational and cultural change within the company. It shows that the success of a RSC project depends on the involvement of internal and external actors of the supply chain.

The model and theoretical propositions raise a range of questions regarding managerial and organizational implications. Nevertheless, our findings contribute to our understanding of the dynamics involved in the RSC design. While our framework and theoretical propositions are a starting point providing directions on the relationships between the main concepts, more research is needed to develop hypotheses which further specify the causal links.

Appendix

Case study research protocol

I. Research questions/issues covered in the interviews and meetings.
- Why set up a RSC?
  - What are the economic drivers for setting up a RSC?
  - What are the environmental drivers for setting a RSC?
  - What are the social drivers for setting up a RSC?
- What are the main conditions to be taken into account in the procurement chain, the production chain, and the distribution chain?
- How can these conditions be satisfied?
  - What is the impact of coordination on adopting a market orientation?
  - What is the impact of coordination on adopting the design for remanufacturing?
  - What is the impact of coordination on reducing uncertainties in the procurement chain?

II. Methodology/case study design

A. Single case study design
- Case study multidisciplinary meetings organized as co-development discussions
- Propositions will be explored from a practitioner perspective
- Different mindsets of functional representatives will be captured

B. Case study selection

Company meets the relevant validity criteria of the research:
- Predisposition to the concept of RSC and remanufacturing
- Access ensures that RSC can be explored from a cross-functional perspective using key informants
- The focus on the French market which is driven by a leasing business model favorable for remanufacturing

C. Interview protocol

The final interview protocol was developed with the assistance of two practitioners who were in charge of the RSC project within the company targeted for this study. These individuals provided valuable corrections to the original interview protocol. The interview protocol was designed to be easy to understand and easy to answer. Also, anonymity was offered to respondents. Respondents were selected based on their direct knowledge of the subject of remanufacturing and, therefore, their ability to answer the questions properly.

III. Data collection - sources of evidence
1. Interviews with head of departments - key source of information
2. Multidisciplinary meetings
3. Direct observations
4. Documentation
   - Internal reports and documents
   - Bill of materials and product design structure
   - Market reports and sale volumes by range of products

IV. Data analysis
1. Pattern matching
   - Look for patterns based on drivers for RSC implementation
   - Patterns based on uncertainties in the procurement chain

- Patterns based on design for remanufacturing
- Patterns based on market orientation of remanufacturing
- Associations based on how coordination is important for reducing uncertainties in the procurement chain
- Associations based on how coordination is important for facilitating design for remanufacturing
- Associations based on how coordination is important for market orientation of remanufacturing

2. Explanation building
   - Single case study: risk of misrepresenting the associated findings
   - No intention to generalize the findings, but to describe the causal powers between the concepts investigated

Competing interests
The authors declare that they have no competing interests.

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