586 LECTURE NOTES IN ECONOMICS AND MATHEMATICAL SYSTEMS

Baptiste Lebreton

Strategic Closed-Loop Supply Chain Management

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To Andrea, for her unbelievable love and patience

Preface

The present PhD thesis is the result of my work as a research assistant at the University of Augsburg, Germany, between 2001 and 2005. Even if a PhD is an individual work, I would like to take the opportunity to thank all the people that have, directly or indirectly, contributed to the completion of this monograph.

First of all, I am very grateful to my PhD mentors, Professor Axel Tuma and Professor Bernhard Fleischmann for giving me the opportunity to complete my Masters degree in Germany and for allowing me to stay in Augsburg to write a PhD thesis. Professor Fleischmann's enthusiasm in solving optimization problems and Professor Tuma's way of managing a research team have been a great inspiration. I would also like to express my gratitude to Professor Luk Van Wassenhove for his support during the final phase of my thesis as well as for the exciting projects I currently work on as a postdoc under his supervision.

Research projects with German, French and Belgian companies have highly contributed in the last three years to focus on current problems faced by companies and to keep in touch with real life. Developing applicable models and concepts for their purposes has been challenging but helped me significantly to improve this monograph. In this context, I would like to thank Roger Bloemen from Solutia Inc. and Olaf Schottstädt from Knorr-Bremse AG for their trust and open-mindedness towards scientific approaches.

Furthermore, I am very indebted to my colleagues and friends (the one seldom excluding the other) that I met during the long sojourn in Augsburg and who made the return to France much more difficult than I expected. Since the list would be very long and I don't want to forget anybody, the folks that have been invited for a cup of coffee at

my office or for a glass of French wine at home should feel concerned by these acknowledgements...

I would like to thank my family and especially my parents, Bertrand and Monique, for their unconditional support throughout the years. Raising my children as good as they did with me will definitively be a challenge... Finally, I am very grateful to my wife Andrea for her love and patience with a husband who makes his job his hobby. Fofinha, eu dedico-lhe este livro!

Fontainebleau, June 2006 *Baptiste Lebreton*

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Part I

Setting Up Closed-Loop Supply Chains

1

Introduction

Museums preserve our past, recycling preserves our future.
Theodor W. Adorno

1.1 Sustainable Supply Chain Management

The fact that manufacturers have to rethink their supply chain in order to ensure the future of their business has been recognized at least since 1972 and the publication of a Club of Rome's report entitled *The limits to growth* (Meadows et al., 1972). The availability of non-renewable resources such as metals or oil is critical for Original Equipment Manufacturers (OEMs) which, generally speaking, need these resources to produce goods. Since OEMs base their business on product selling, the long-term availability of these resources is required for the profit creation to continue. By now, the profit-maximization objective stands in contradiction with the objective of resource conservation. This can be illustrated with the following example: Given a manufacturer with a turnover of X units, a margin per unit of $\sigma - \kappa$[1] and a resulting profit of π (eq. 1.1). To sell his products, the OEM requires R non-renewable resources at a consumption rate α (eq. 1.2). Since α is positive, it can be stated that profit maximization implies maximization of the resource consumption (eq. 1.3).

$$max \quad \pi = (\sigma - \kappa) \cdot X \tag{1.1}$$

$$where \quad \alpha \cdot X = R \tag{1.2}$$

$$max \quad \pi \Rightarrow max \quad R \tag{1.3}$$

[1] σ = retail price, κ = production costs

However, in order to improve the sustainability[2] of their business, OEMs have to reduce the value of their α coefficient. This can be achieved either by reducing the resource consumption (throughput) within the supply chain or by reintegrating already consumed resources into the supply chain. Hence, the consumption rate α can be broken down into the production throughput rate γ and the resource reintegration rate μ (eq. 1.4).

$$\alpha = \gamma \cdot (1 - \mu) \tag{1.4}$$

$$\alpha \rightarrow 0 \Leftrightarrow \gamma \rightarrow 0, \quad \mu \rightarrow 1 \tag{1.5}$$

Schmidt-Bleek (1998) and von Weizsäcker et al. (1995) provide examples improving the material intensity per service unit (with a strong emphasize on $\gamma \rightarrow 0$). Nevertheless, the productivity jumps described are difficult to realize without a complete paradigm change towards service selling instead of product selling. Stahel (1986), Giarini and Stahel (1989) and Kostecki (1998) demonstrate in a similar fashion the shortcomings of the product selling concepts illustrated in equation 1.3. Improvements of the γ rate, as depicted in Porter and van der Linde (1995) as well as Romm (1999), are noticeable but not sufficient to completely suppress the consumption of additional non-renewable inputs R.

As Kopicki et al. (1993) or Thierry et al. (1995) show, an increase of the reintegration rate μ can be achieved at multiple levels also called recovery paths: Product level (*reuse, repair*), component level (*remanufacturing, cannibalization*) or material level (*recycling*). Depending on the recovery path, the reverse flows are processed through five generic activities: *Acquisition, selection, disassembly, cannibalization* and *mechanical processing* (see fig. 1.1).

The *acquisition* process consists of getting the product from the market to the point of recovery. This involves two core activities which are the collection and the procurement process. The procurement process has critical role when the OEM has no property rights on the initial product and the used cores still have a high residual value at the end-of-cycle or end-of-life. Toner cartridges manufacturers are for instance competing against independent remanufacturers cannibalizing their demand for new, more expensive, cartridges (see chapter 4). The role of procurement is also to set incentives to reclaim the valuable

[2] Sustainable development is defined as the ability to *"meet the needs of the present generation without compromising the ability of future generations to meet their own needs"* (The World Commission on Environment and Development, 1987).

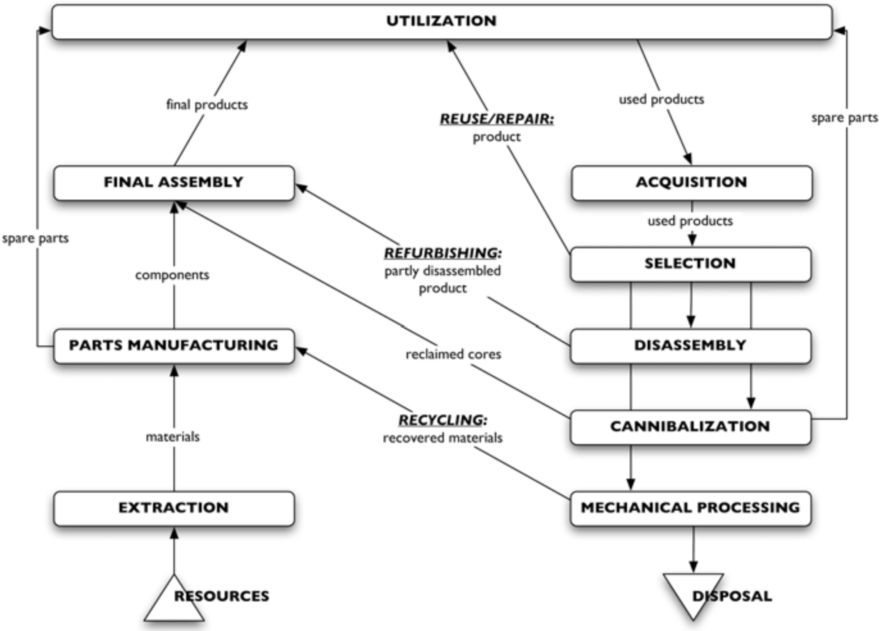

Fig. 1.1. Asset recovery processes: Overview (modified from White et al. 2003)

cores, especially when these are stuck in a retailer's channel. This situation is particularly critical when an OEM faces distribution returns such as product recalls, unsold items or stock adjustments (de Brito and de Koster, 2004). Blackburn et al. (2004) sustain this point of view by introducing the concept of marginal value of time (MVT). The authors conclude that for goods with a quick residual value loss but high initial value, the reverse supply chain should be reactive (lead time minimizing) instead of functional (cost minimizing).

The collection process depends on the organization of the reverse channel (Beullens et al. 2004, Rinschede et al. 1995). On-site collection gives the possibility to manage synergies between forward and reverse distribution since on-site services are often performed by the OEM itself or by sales representatives. Resulting synergies are identified by Beullens et al. (2004). While on-site collection generally deals with industrial, maintenance-intensive goods, consumer products are often reclaimed through the retailers' channels, especially when the products are still under guarantee. End users generally dispose of end-of-life products to municipal waste systems. In this case, we conclude that manufacturers are not interested in reclaiming their waste flow since they could have provided incentives to acquire their end-of-life products. This situation can be currently observed in Germany for the electrical and electronic equipment (computers, mobile phones or printers) that are either reclaimed by independent traders for reselling on secondary markets or disposed of.

According to Flapper (2003), incentives are the leverage for reclaiming valuable products. The author differentiates in this context between financial and organizational incentives. Financial compensations allow a customer to reduce his financial burden, either through a buyback option, rebates for a new product or a cost-free take-back. Buyback options are problematic as they should be set ex-ante although OEMs have no advice about the future value pattern of their products. Flapper points out that customers will make use of this option when they are not able to resell their used product on the secondary market at a higher price than the buyback reward. In other words, if the buyback incentive is set higher than the market price, an OEM will pay more than it would do if procuring on the market. If the incentives are too low, customers will prefer to resell on the secondary market rather than to the OEM. A deposit fee presents similar benefits and shortcomings than a buyback option: Returns will be guided to the secondary or the grey market when the residual value of the product surpasses the deposit fee. Organizational incentives modify the property rights so that customers are obliged to return the used products to the OEM after a given period. In leasing or rental contracts, for instance, the customers pay for using the product instead of buying it. The OEMs involved have therefore the possibility to reduce the insecurity concerning the reverse flow structure (quality, timing, quantity) and are thus able to embed reverse flows into their decision-making process (see Guide and van Wassenhove, 2001 and Fleischmann, 2001 for the impact of insecurity on planning).

Once the cores have been returned, the *selection* process takes place in which the valuable products are identified and guided to one of the recovery processes or directly resold. We notice that the term "valuable" also requires to know whether a demand for this product or its parts exists and if the upcoming recovery costs do not surpass the procurement savings for new components. This decision implies a good coordination between procurement (how many parts are required to match the demand?), inbound logistics (is there any part on stock?), marketing (is there currently a demand for the final product?) and service (is there a demand for the recovered spare parts?). The ability to manage this information flow may become a core competence for an OEM as it fits in with the criteria of Prahalad and Hamel (1990): Valuable (because it sustains a competitive edge), knowledge-based and hardly imitable for competitors.

After having filtered out the recoverable items, an OEM may choose between two alternatives for closing the loop at a component level. Thierry et al. (1995) differentiate in this case between *disassembly* and *cannibalization*. Disassembly consists of removing all the parts from a returned product and reintegrating them into the assembly process whereas cannibalization is equivalent to a very selective disassembly: Only the valuable parts are removed while the residual product is sent to the mechanical processing step. The *mechanical processing* step encompasses the shredding of residual products or components and the sorting of the resulting material fractions. The shredded residual that cannot be reintroduced as material into the supply chain is either landfilled or incinerated.

Nevertheless, despite the necessity of resource reintegration, closed-loop supply chains, i.e. supply chains simultaneously carrying both forward and reverse flows, are very seldom run by Original Equipment Manufacturers. Guide (2000) estimates for instance that 95% of the remanufacturing[3] programs are **not** managed by the original producers. To the knowledge of the author, this figure should be even inferior for recycling programs due to the low level of vertical integration of manufacturers.[4] In this context, it is not surprising to see OEMs being compelled by legislators to at least finance the reintegration of resources and thereby to increase their own μ rate. Table 1.1 gathers the current environmental legislation setting reintegration rates. We notice that the most recent legislation: The Waste Electrical and Electronic Equipment (WEEE) and the End-of-Life Vehicle (EOLV) directives set only material reintegration (recycling) targets and do not mention any product or component reintegration target.

This apparent discrepancy between the critical role of long-term resource availability for a firm's success and the low attention manufacturers have paid to this problem by now is the initiator of this monograph. According to van Wassenhove and Guide (2005), the reverse logistics research does not provide currently insight into this contradictory situation due to the research emphasis on operational and

[3] We will consider remanufacturing and refurbishing as synonym in the following.

[4] German car manufacturers generate for instance only 25% of their products' value (VDA, 2002) so that an improvement of the recyclable fraction of their products does not impact directly an OEM's profits.