DTU Library

Determining the total cost of reverse supply chain operations for original equipment manufacturers

Larsen, Samuel Brüning; Jacobsen, Peter

Published in:
Proceedings of 21st EurOMA Conference

Publication date:
2014

Citation (APA):
Larsen, S. B., & Jacobsen, P. (2014). Determining the total cost of reverse supply chain operations for original equipment manufacturers. In Proceedings of 21st EurOMA Conference: Operations Management in an Innovation Economy University of Palermo.

Determining the total cost of reverse supply chain operations for original equipment manufacturers

Samuel Brüning Larsen
Management Science
Technical University of Denmark

Peter Jacobsen
Management Science
Technical University of Denmark

Abstract
When original equipment manufacturers (OEM) examine whether or not to invest in a reverse supply chain (RSC), managers need insight into not only the cost savings and new revenue streams the RSC enables, but also the total cost of the RSC itself. Using case study research the study examines what cost parameters constitute the total cost (TC) of the RSC. The specific RSC that the study seeks the TC for consists of 1) end-product refurbishing, 2) component refurbishing, and 3) sales of used materials back to original suppliers or independent recyclers for materials recycling.

Keywords: Reverse supply chain, reverse logistics, total cost, cost parameters, original equipment manufacturer, supply chain management, sustainability in operations and logistics

Introduction
Increasing virgin material prices, sustainability-aware consumer segments, and opportunities for strengthening competitive advantages make reverse supply chain (RSC) operations that recover used products and recycle materials attractive (Stock et al., 2002; Ginsberg and Bloom 2004; Geyer et al., 2007). Within both academia and industry the RSC subject has received increasing attention over the past two decades for both the reasons stated above and regulations forcing producers to take an extended producer responsibility (EPR) for their products after their end-of-life (Dowlatshahi, 2010; Ilgin and Gupta, 2010; Seitz, 2010; Gui et al., 2013; Lifset et al., 2013). The EPR may include recovery of materials or proper disposal. Examples of industries where EPRs apply are white goods, automobiles and electrical equipment.

The RSC-definition by Guide and Van Wassenhove (e.g. Guide and Van Wassenhove, 2002, or Guide et al., 2003), which is prevalent within the field of operations management (OM), describes the RSC as a chain of five connected processes. Figure 1 depicts the RSC. This study chooses the definition by Guide and Van Wassenhove not only because of its prevalence within OM, but because the definition encompasses the whole RSC end-to-end (albeit on an overall level). The definition views the RSC as a flow beginning and ending in the customer market. Using and end-to-end view of the RSC increases the probability of including all relevant costs in the RSC's total cost (TC).

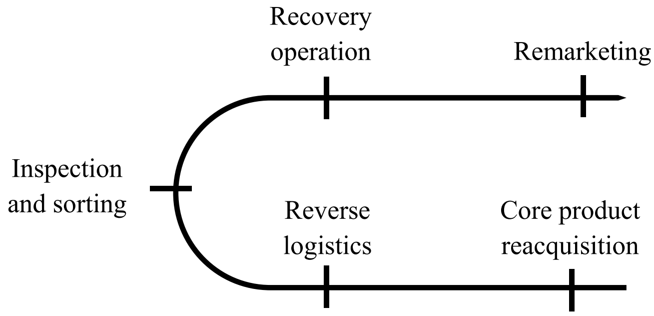


Figure 1 The Reverse Suppy Chain (Guide and Van Wassenhove, 2002)

The chain begins with reacquiring used products from the market. These products are labeled "core products" (or simply "cores") in RSC literature to distinguish them from virgin products (e.g. Teunter, 2011). When products are reacquired the RSC moves them to an inspection and sorting facility through the process of reverse logistics. At the inspection and sorting facility the core products are inspected for the determination of the proper recovery or disposal stream (e.g. direct reuse, refurbishing, component salvage, or incineration). The fourth step is the recovery process that may include cleaning, disassembly, exchange of worn components, reassembly, and test procedures. Finally, the fifth step remarkets the recovered products to primary or secondary markets.

Today, the understanding of RSCs is still very limited (Kocabasoglu et al., 2007) and knowledge about the economics of RSCs is scarce (Guide et al., 2003; Huscroft et al., 2013). Without a complete picture of the TC of both implementing and operating a RSC, managers are unable to assess the net value that RSC operations deliver to the firm as well as compare investments in RSC operations with other investment opportunities. Figure 2 illustrates the RSC's costs as well as potential cost savings and revenues in an investment perspective.

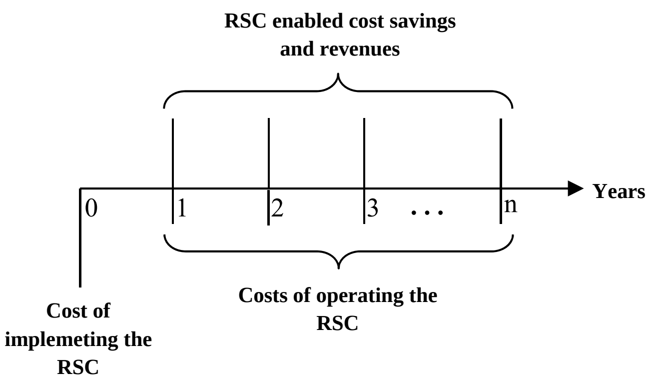


Figure 2 – The RSC as an investment. Adapted from Cross et al. (1996)

This study develops a framework that allows managers to determine the TC of implementing and operating a RSC. The TC-framework will consist of the total set of *cost parameters* that constitute the TC. Two examples of cost parameters described in extant literature are 1) the cost of core product collection and 2) the cost of core product inspection (Geyer et al., 2007). The objective of this study is to show the vast and diverse amount of cost parameters that constitute the TC of a RSC.

In the study the focal entity is an OEM with the following characteristics: 1) the OEM's internal processes in the forward supply chain include end-product assembly and fabrication of *some* components, while remaining components and all materials are purchased from suppliers; 2) in addition to their primary market for complete products the OEM serves an aftermarket for components; 3) both complete products and components are durable and have potential for recovery and remarketing in primary as well as in secondary markets. For the remainder of the article an OEM with these characteristics will be referred to as "the focal OEM".

According to Thierry et al., (1995) there are five product recovery options an OEM's RSC can include: 1) repair, 2) remanufacturing, 3) refurbishing, 4) component salvage, and 5) materials recycling. The single case in Thierry et al.'s article describes Xerox's RSC that recovers their "Green Line" series of copy-machines. Xerox's rather comprehensive RSC includes repair, remanufacturing, component salvage, and materials recycling. However, which specific options, that are economically feasible for an OEM, may depend on type product, material, customer purchasing criteria, costs of recovery etc.

Several academics address the distinction between high-value recovery versus low- or no-value recovery (e.g. Kocabasoglu et al., 2007; Simpson, 2010). Some suggest a RSC that recovers items in a cascading fashion where high-quality cores are recovered through refurbishing (high-value recovery), and remaining low-quality cores are recovered through component refurbishing and materials recycling (low-value recovery) (e.g. Guide and Van Wassenhove, 2006). For the defined focal OEM the study develops a TC framework that includes several recovery options and applies them by cascading from high- to low-value recovery.

A TC framework depends highly on what specific recovery options the RSC performs for the firm. Thierry et al. (1995) describes which general product recovery options an OEM has. One might argue that Thierry et al.'s set of options in fact is a set of option-*categories*. The argument is that e.g. remanufacturing can be conducted for both end-products or for components and with a variety of end-destinations for the recovered items. At this point we introduce the term *RSC-function*. An RSC-function details not only 1) the specific recovery operation in the RSC (e.g. remanufacturing or refurbishing), but also 2) which items the operation recovers (e.g. end-products, components, and/or materials) and 3) the items' end-destinations (e.g. resale in secondary markets or reuse as spare parts). Examples of RSC-functions are 1) "Remanufacturing of core end-products for resale in secondary markets", 2) "refurbishing of core components for reuse as spare parts in maintenance programs of products in the OEM's installed base", and 3) "recycling of core materials for reuse in virgin products". The RSC of the focal OEM contains the set of RSC-functions listed below.

1. Refurbishment of end- products for resale in secondary markets and for resale in primary markets as a low-cost version of the virgin product
2. Refurbishment of components for reuse in refurbished products and for resale as spare-parts in the aftermarket
3. Resale of used materials upstream in the supply chain to either current suppliers of virgin materials or independent recyclers

The set of RSC-functions support the objective of the study stated earlier of developing a TC framework of a RSC that cascades from high- to low-value recovery. Furthermore, the set fits with the characteristics of the focal OEM. Figure 3 illustrates the RSC containing the three RSC-functions.

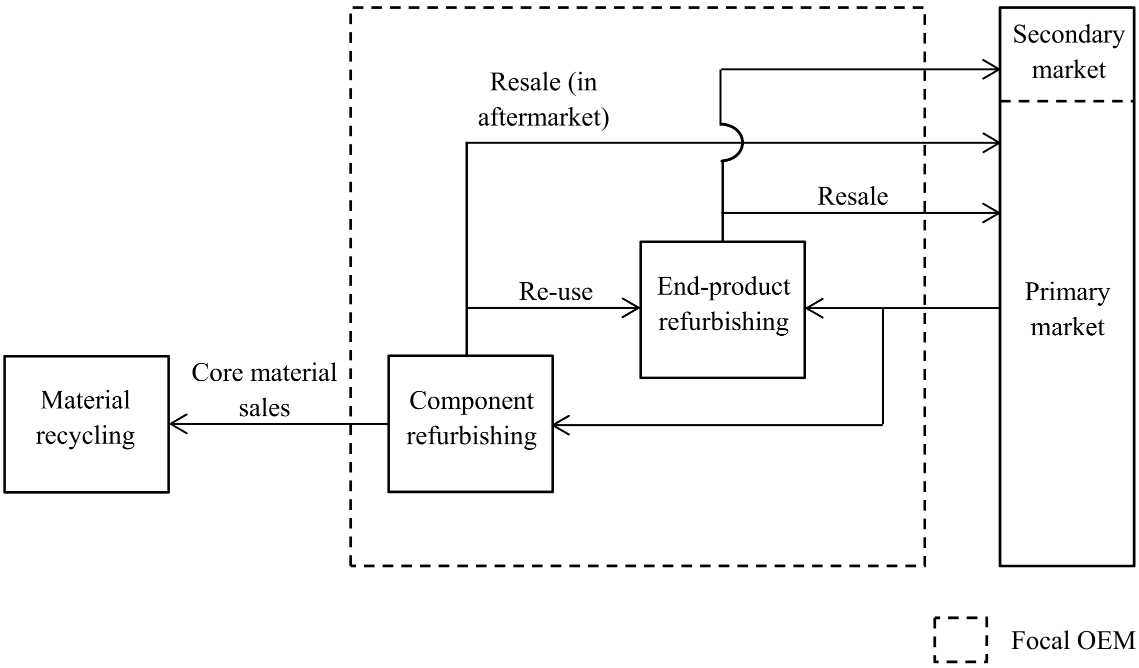


Figure 3 The focal OEM's RSC

Some argue for differences between end-of-use (EOU) and end-of-life (EOL) returns, while others argue for differences between high- and low-quality returns. Guide and Van Wassenhove pair EOU products with remanufacturing and EOL products with component recovery and materials recycling (Guide and Van Wassenhove, 2009). In the focal OEM's RSC all reacquired core products enter the RSC in the same way and the first screening process determines each products proper recovery operation.

Literature Review

The objective of the review is to identify the RSC processes and costs already described in academic writings. To support the objective the review is divided into 1) the RSC-investment and 2) the RSC operating processes and costs. Operating processes and cost are subdivided into the five major processes in the RSC-definition by Guide and Van Wassenhove described earlier.

Investment costs for RSCs are among the least described RSC costs in extant literature. Investment costs are part of RSC profit calculations most often as a fixed number that is not elaborated further (e.g. Salema et al., 2010; El korchi and Millet, 2011). One explanation can be that fixed costs in remanufacturing are relatively low as most processes are manual (for e.g. inspection and testing). However, some papers articulate content elements of the investment. One example is Kajendirakumar et al. (2007), who state that commercial recycling chains require high investment for specialized recycling installations and equipment.

Operating cost parameters of RSCs are explored much more than the initial RSC-investment. One example is Geyer et al. (2007), who describes a number of RSC cost parameters: Cost of collection, cost of inspection, cost of product recovery, and cost of disposal for those products that cannot be recovered. All parameters are variable costs and do not include investment costs.

The first of the five processes in the RSC described on page 1-2 is product core reacquisition. The process of reacquiring core products, initially termed "product acquisition management" by Guide and Van Wassenhove (2001), is a proactive management attempt at ensuring an inflow of cores to the RSC. Östlin et al. (2008) has identified seven different ways of product core reacquisition of which most include a reacquisition cost for the OEM. Product core reacquisition is a process reasonably well-described in academia.

The second process, reverse logistics, is the physical transport and inventory processes that take back core products from customers and deliver them at the OEM's inspection and sorting facility. Reverse logistics is among the most investigated terms within RSC literature. Se for example the reviews by Sasikumar and Kannan (2008) or Pohkarel and Mutha (2009). Reverse logistics costs depend on the specific set-up of the OEM, but include costs of physical collection, transport, materials handling, and inventory holding. A recent article on reverse logistics costs is Atasu et al. (2013) about the structure of collection costs.

Inspection and sorting constitutes process number three. Costs for both activities are examined in academia. Examples are Galbreth and Blackburn (2006), who examine how selective to be during sorting, and Robotis et al. (2012), who examine the relationship between inspection capabilities and remanufacturing cost uncertainty.

Product recovery processes and the costs thereof differ depending on the RSC-function the RSC performs. With few exceptions all product recovery operations require some level of product disassembly as an initial step. One exception is the "grind and sort" process from Pagell and Wu (2007). Ghoreishi et al. (2013) model the costs of recovery of the disassembled cores and include costs of reassembly, test and quality inspection.

Although the fifth process of remarketing is included in many articles including many of the already cited works, the cost of the process is not examined well. Some argue for the difficulties in finding markets for used products (e.g. Theirry et al., 1995, and

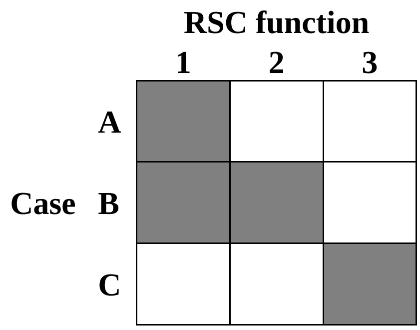
Kocabasoglu et al., 2007), but the cost of both the initial investment in market development and the continuous process of remarketing and selling used products remains unexplored. However, one cost of remarketing recovered products to primary markets is the cost of cannibalized virgin product sales. Cannibalization has received some attention over the last decade is. Examples of articles are Atasu et al., 2010, and Guide and Li, 2010.

Research Method

The article is exploratory in nature asking the question of what cost parameters constitute the total cost of the RSC of the study's focal OEM. The overall research method combines the results of the literature study with case study research. According to Yin (2014) case study research is relevant for the category of exploratory "what"-questions. The following section describes the study's case sampling principle and the sources of data.

The objective of the case sampling is finding a *set of cases* that in combination cover the RSC of the focal OEM. A preliminary sample of eight potential case firms was examined for potential inclusion in the study. All of these eight firms have the same set of characteristics as the focal OEM of the study. Three case firms were chosen for the study based on the criteria that the aggregate of the cases cover the entire RSC of the focal OEM. Figure 4 shows how the three cases cover the RSC of the focal OEM.

Figure 4 How the three RSC-functions in the focal OEM's RSC are covered by the three cases



All three cases are global companies with manufacturing and sales on several continents. The names of the firms are concealed for confidentiality and referred to as Case A, Case B, and Case C. Case A produces industrial measurement equipment; Case B, medical equipment; and Case C, water distribution equipment.

One might argue why the study does not simply use one single case encompassing all three RSC-functions. Furthermore, one might argue that if such cases only seldom exist, what is then the relevance of the study. Although the three RSC-functions are applied in practice individually, a single case that includes all three RSC-functions is in fact difficult to find (even though many firms come close and Case C is in the process of examining RSC-functions 1 and 2). However, the relevance of the study is still high. The study follows the argument by Pagell and Shevchenko (2014) that academia should get ahead of practice within sustainable supply chain research and focus on the question of “How to be sustainable?”. The chosen set of RSC-functions is exactly that: (one step) ahead of practice.

The sources of data for the case study consists of interviews with key employees, observations (e.g. plant tours), written descriptions of case firms and their customer-markets, and product white papers. The overall method is mapping of case firm’s reverse flow to identify all activities, processes and explicit costs of the RSC. When a data source reveals that a process or activity is part of a case firm’s RSC, then the equivalent cost parameter for that process or activity is included in the set of cost parameters that constitute the total cost of the RSC. Example: A source of data reveals that a case’s RSC includes a process of core product inspection. The study will then include the cost parameter “cost of core product inspection”.

Case analysis

The objective of the case analysis is to develop a set of cost parameters for implementing and operating a RSC that has the RSC functions described on page 3.

The section is structured as follows: First, each case firm’s RSC is briefly described, and second, the analysis integrates cost parameters from all three cases in one set. The second step will include cost parameters identified in the literature review.

Cases A, B, and C

Case A is an original equipment manufacturer of low-volume high-quality industrial measurement equipment that is used directly within customers’ manufacturing systems to measure specification conformance (e.g. liquid purity). In developed markets (Western Europe and North America) where customers purchase high-priced virgin products the OEM tries to reacquire the core products, when customers purchase new products. If possible, the OEM reacquires the core product by giving the customer a deduction in the sales price of the new product. When a core is reacquired, it is sent directly from the location of reacquisition to an emerging market (e.g. Eastern Europe or South East Asia). The local business unit (BU) refurbishes and resells the product to customers who value a lower priced refurbished product.

Case B is an original equipment manufacturer of low-volume high-quality medical equipment used in hospitals. Core components are collected from equipment that is either within the installed base during service or from equipment coming back through the RSC. Components are collected and shipped to a central site as whole batches. At the central site the components are refurbished in-house or they are shipped to the original supplier for refurbishing. After refurbishment components can be used in refurbished products or for servicing the installed base as spare parts.

Case C is an original equipment manufacturer of high-volume high-quality standardized water distribution equipment. Core product reacquisition takes place in the same way as with Case A and B; the OEM buys back core products from the market. A difference is, however, that products go through installers and whole-sellers back to the OEM’s facility. At the facility the core products are disassembled into core materials that can either be sold for recycling or disposed. Disposed materials can also be recycled, but do not result in revenue for the OEM.

Results from analysis

The tables below presents the total set of cost parameters derived from the three cases as well as the literature review. Table 1 presents the investment costs of implementing the focal OEM's RSC and Table 2 presents the operating costs. The letters A, B, C, and L in the parenthesis represent the data source of each cost parameter. A, B, and/or C indicate Case A, B, and/or C as the source(s). L refers to the literature review presented earlier in the paper. If a cost parameter has several letters then the parameter is supported by several sources.

Table 1 RSC investment cost parameters

Investment costs
Cost of introducing take-back of core products with current customers (A, B, C)
Cost of hiring and training new employees for disassembly, product test, and logistics (A, B, C)
Cost of new equipment for dissassembly and refurbishing (A, C)
Cost of initial introduction of "new" products to new and existing markets (A, B)

Table 2 RSC operating cost parameters

Operating costs				
Core product reacquisition	**Reverse logistics**	**Inspection and sorting**	**Recovery operation**	**Remarketing**
Buy-back costs of core items (A, B, C, L)	Costs of collecting core items (A, B, L)	Cost of inspection, sorting (A, L)	Costs of product dissasembly (A, C)	Cost of continous remarketing to new and exist. markets (A, B)
Cost of adm. take-back from customer for local BU (A, B)	Core items inventory holding costs at local BU (A, B)	Cost of initial product test (A)	Cost of a standard exchange of wear components (A)	Cost of selling core products prior to recovery (MTO) (A)
Cost of initial screening (recovery or disposal)(A)	Order picking and shipping costs from local BU (A, B)	Cost of cleaning products and components (B)	Cost of refurbishing incl. reassembly (A, L)	Cost of administrating the order process (A, B, C)
Cost of disposal of non-recoverable items (A, B, C)	Transport costs from local BU to central site (A, B)	Cost of inserting working products into forward flow (A)	Cost of final product or compoent test (L)	Cost of cannibalized virgin product sales (L)
Adm. of payment btw. local BU and central site (A, B)	Materials handling costs when receiving core items (A, B, C)			
	Core items inventory holding costs at central site (A, B, C)			

Table 3 presents 23 cost parameters for operating a RSC. Almost half are within Core product reacquisition and reverse logistics. However, the number of cost parameters does not determine the relative size in operating costs.

Conclusions and future research opportunities

Tables 1 and 2 present the findings of the study. The costs of the RSC are diverse in nature and spread across several organizational functions including inbound logistics, inventory, manufacturing, marketing and sales. The set of investment cost parameters is short and does not suggest major investments. Both the case research of this study and the scarcity of investment cost parameters described in extant literature suggest low investment costs in RSC implementation. However, the literature review gives reason to believe that if the RSC of the focal OEM had included materials recycling as an in-house process, the investment in recycling facilities would sharply increase the investment amount. The same could be argued for products that place heavy demand on disassembly or chemical cleaning processes.

One question is which cost parameters are idiosyncratic to the cases of the study and which are generic and apply to all RSCs of OEMs with the characteristics of the study's focal OEM. Given that the study is relying on the prevalent RSC definition in the OM field, the cost parameters build on the RSC-framework already accepted in the OM field. However, the findings of the study rely on a small set of cases and one could argue that the external validity of the study is relatively narrow. Given the nature of the three case firms' products, which are all manufactured from a minimum of 95% plastic components of which some are electronic in nature, cost parameters that apply to other types of firms could be identified.

Given the restrictions on the external validity of the study's results, a future research need is validation of the cost parameters identified in the study. Validation could take place through comparative case studies with case firms from different industries where products are made from differing materials (e.g. types metals). Survey research could validate the prevalence of the cost parameters found in this study. A further future research opportunity is presenting the TC or facets of the TOC in mathematical models.

The results of this study can be viewed as a first step towards identifying the whole set of cost parameters constituting the TC of an OEM's RSC.

References

Atasu, A., Guide Jr, V. D. R., & Van Wassenhove, L. N. (2010), "So what if remanufacturing cannibalizes my new product sales", *California Management Review*, Vol. 52, No. 2, pp. 56-76

Atasu, A., Toktay, L. B., & Van Wassenhove, L. N. (2013). How collection cost structure drives a manufacturer's reverse channel choice", *Production and Operations Management*, Vol. *22, No.* 5, pp. 1089-1102

Cross, S., Westerfield, R., Jaffe, J. (1996), *Corporate Finance*, IRWIN, USA

Dowlatshahi, S. (2010). "A cost-benefit analysis for the design and implementation of reverse logistics systems: case studies approach", *International Journal of Production Research*, Vol. 48, No. 5, pp. 1361-1380.

El korchi, A., Millet, D.. "Designing a sustainable reverse logistics channel: the 18 generic structures framework." *Journal of Cleaner Production* 19.6 (2011): 588-597.

Galbreth, M. R., & Blackburn, J. D. (2006), "Optimal acquisition and sorting policies for remanufacturing", *Production and Operations Management*, Vol. 15, No. 3, pp. 384-392.

Ghoreishi, N., Jakiela, M., Nekouzadeh, A., (2013), "General modeling framework for Cost/Benefit analysis of remanufacturing", in Gupta, S. (Ed.), "Reverse supply chains: issues and analysis", CRC Press

Ginsberg, J. M., and Bloom, P. (2004) "Choosing the right green marketing strategy", *MIT Sloan Management Review,* Vol. 46, No. 1, pp. 79-84

Geyer, R., Van Wassenhove, L., and Atasu, A. (2007), "The economics of remanufacturing under limited component durability and finite product life cycles", *Management Science*, Vol 53, No.1, pp. 88-100.

Gui, L., Atasu, A., Ergun, Ö., and Toktay, L. B. (2013), "Implementing extended producer responsibility legislation", *Journal of Industrial Ecology*, Vol.17, No. 2, pp. 262-276

Guide Jr, V. D. R., & Li, J. (2010), "The Potential for Cannibalization of New Products Sales by Remanufactured Products*", *Decision Sciences*, Vol. 41, No. 3, pp. 547-572

Guide, V. D. R., Harrison, T. P., and Van Wassenhove, L. N. (2003). “The challenge of closed-loop supply chains”, *Interfaces*, Vol. 33, No. 6, pp. 3-6
Guide, V. D. R., & Wassenhove, L. N. (2001), “Managing product returns for remanufacturing”, *Production and Operations Management*, Vol. 10, No. 2, pp. 142-155.
Guide, V. D. R., and Van Wassenhove, L. (2002), "The reverse supply chain", *Harvard Business Review*, Vol. 80, No. 2, pp. 25-26.
Guide, V. D. R., and Van Wassenhove, L. N. (2006), “Closed-Loop Supply Chains: An Introduction to the Feature Issue (Part 1)”, *Production and Operations Management*, Vol. 15, No. 3, pp. 345-350
Guide, V. D. R. and Van Wassenhove, L. (2009), “The Evolution of Closed-Loop Supply Chain Research”, *Operations Research*, Vol. 57, No. 1, pp.10-18
Huscroft, J. R., Hazen, B. T., Hall, D. J., Skipper, J. B., & Hanna, J. B. (2013). “Reverse logistics: past research, current management issues, and future directions”, *International Journal of Logistics Management*, Vol. *24, No.* 3, pp. 304-327
Ilgin, M. and Gupta, S. (2010), "Environmentally conscious manufacturing and product recovery (ECMPRO): a review of the state of the art", *Journal of environmental management*, Vol. 91, No. 3, pp. 563-591
Kajendirakumar, Ch, V. Soundararajan, and N. Alagumurthi. "Reverse Logistics Trends and Models-A Review." *Journal for Manufacturing Science and Production* 8.1 (2007): 1-14.
Kocabasoglu, C.,Prahinski, C., and Klassen, R. D. (2007), “Linking forward and reverse supply chain investments: The role of business uncertainty”, *Journal of Operations Management*, Vol. 25, pp. 1141–1160
Lifset, R., Atasu, A., & Tojo, N. (2013). Extended Producer Responsibility.*Journal of Industrial Ecology*, Vol.17, No. 2, pp. 162-166
Östlin, J., Sundin, E., and Björkman, M. (2008), ”Importance of closed-loop supply chain relationships for product remanufacturing”, *International Journal of Production Economics*, Vol. 115, No. 2, pp. 336-348
Pagell, M. and Shevchenko, A. (2014), “Why research in sustainable supply chain management should have no future”, Journal of Supply Chain Management, Vol. 50, No. 1, pp. 44-55
Pagell, M., Wu, Z., & Murthy, N. N. (2007), “The supply chain implications of recycling”, *Business Horizons*, Vol. 50, No. 2, pp. 133-143
Pokharel, S., & Mutha, A. (2009), “Perspectives in reverse logistics: a review”, *Resources, Conservation and Recycling*, Vol 53, No. 4, pp. 175-182
Robotis, A., Boyaci, T., & Verter, V. (2012), “Investing in reusability of products of uncertain remanufacturing cost: The role of inspection capabilities”, *International Journal of Production Economics*, Vol. 140, No. 1, pp. 385-395
Salema, M., A. Barbosa-Povoa, and A. Novais. "Simultaneous design and planning of supply chains with reverse flows: a generic modelling framework." *European Journal of Operational Research* 203.2 (2010): 336-349
Sasikumar, P., and Kannan, G. (2008), “Issues in reverse supply chains, part II: reverse distribution issues–an overview”, *International Journal of Sustainable Engineering*, Vol 1, No. 4, pp. 234-249
Seitz, M. A. (2007). A critical assessment of motives for product recovery: the case of engine remanufacturing”, *Journal of Cleaner Production*, Vol. *15, No.* 11, pp. 1147-1157
Simpson, D. (2010), “Use of supply relationships to recycle secondary materials”, *International Journal of Production Research*, Vol. 48, No. 1, pp. 227-249
Srivastava, Samir K. "Value recovery network design for product returns." *International Journal of Physical Distribution & Logistics Management* 38.4 (2008): 311-331.
Stock, J., Speh, T., Shear, H. (2002), “Manny Happy (Product) Returns”, *Harvard Business Review*, Vol. 80, No. 7, pp. 16-17
Teunter, R. H., and Flapper, S. D. P. (2011), ”Optimal core acquisition and remanufacturing policies under uncertain core quality fractions”, *European Journal of Operational Research*, Vol. 210, No. 2, pp. 241-248
Thierry, M., Salomon, M., Van Nunen, J., and Van Wassenhove, L. (1995), “Strategic Issues in Product Recovery Management”, *California Management Review*, Vol. 37, No. 2, pp. 114-135
Yin, R., (2014), “Case Study Research”, SAGE publications