Reverse Logistics – a review of case studies

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Abstract	Products, components, materials and other equipment stream forward and back wards and back in their supply chains. Reverse Logistics deals with the processes associated with the reverse stream from users/owners to re-users. This paper provides a review and *content analysis* of scientific literature on reverse logistics case studies. Over sixty case studies are included. In addition, we give an overview of particular issues, which we link with propositions, unanswered questions and thus directions for future research.	
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Reverse Logistics – a review of case studies

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Abstract: Products, components, materials and other equipment stream forward and back wards and back in their supply chains. Reverse Logistics deals with the processes associated with the reverse stream from users/owners to re-users. This paper provides a review and *content analysis* of scientific literature on reverse logistics case studies. Over sixty case studies are included. In addition, we give an overview of particular issues, which we link with propositions, unanswered questions and thus directions for future research.

Key words: Reverse Logistics, Case studies, and Content Analysis.

1. Introduction

Products, components, materials and other equipment stream forward and backwards in their supply chains. Reverse logistics has been the increasingly growing academic field and practice that deals with the processes associated with the reverse stream from users/owners to re-users. During the early nineties, the Council of Logistics Management started publishing studies where reverse logistics was recognized as being relevant both for business and society (Stock, 1992). Other studies followed stressing the opportunities on reuse and recycling (Kopicki et al., 1993) In the late nineties, Kostecki (1998) discussed the marketing aspects of reuse and extended product life. Stock (1998) reported in detail how to set up and to carry out reverse logistics programs. Rogers and Tibben-Lembke (1999) presented a broad collection of reverse logistics business practices, giving special attention to the US experience (see also Lund, 2001). Recent reviews and literature compilation either on models to support reverse logistics or on the business perspective can be found at Fleischmann et al., 1997, Guide et al.,

2000, Guide and van Wassenhove, 2003, and Dekker et al., 2003. Furthermore, during the last years, many articles dedicated to the analysis of the practice of reverse logistics have appeared, including Canon (Meijer, 1998), Philip Morris (Andriesse, 1999), Esteé Lauder (Meyer, 1999), Kodak (Toktay et al., 2000) and Nortel Networks (Linton and Jonhson, 2000). One can not provide proper insights into reverse logistics without being familiar with how firms are dealing with it in practice, which are the trade-offs, how decisions are being supported and so on. Case study literature can be extremely helpful in getting this knowledge.

Quite some case studies on reverse logistics have been described in the literature dealing with different industries, recovery options and drivers. This literature is however scattered over journals for very different research communities. Besides this, in countries in the forefront of reverse logistics a substantial number of case studies have been published in the local language and therefore not accessible for the majority of the research community.

In this paper we provide a content analysis of more than sixty articles portraying how firms and other organizations deal with reverse logistics. We cover the whole range of recovery options and driving forces with cases from several continents. We report eye-catching elements and we link it to propositions, unanswered questions and research directions.

The remainder of the paper is organized as follows. First we describe the methodology used for finding and classifying the case studies presented in this paper. Next we provide overall statistics regarding type of industry, product and the geographic area of the cases. After that, we discuss the case studies, and present observations, propositions and research opportunities. We end with some final remarks and research directions.

2. Methodology

By case study we mean an in-depth description of the practice, the circumstances and its characteristics leading to an understanding of the situation within its own context (see Stake, 1995). Note that this definition rules out mere examples short on details.

The search procedure was as follows. We inspected the Science Citation, and the ABI/Inform online libraries, using the combination of key words listed in Appendix A. We also surveyed literature that is especially dedicated to the topic, like the Handbook of reverse logistics and proceedings of renowned conferences, namely the APICS Reman and IEEE on Electronics and the Environment (see electronic libraries). The main search took place in early 2001 but continued till end 2002.

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To give the reader the overall reverse logistics context, we gathered the following documentation for each case study:

- Product-in (entering the chain), foremost recovery activity and product-out (leaving the chain);
- Actors with their function in the chain (sender, collector, processor, customer and initiator);
- Return reason for sender and driving force for initiator of the recovery process;

The previous information is summarized in Tables in Appendix B. A cell is left empty when the correspondent information is not available. The type of information, as described above it was not randomly selected. Former studies have argued that the processes, actors, types of reuse and actors are relevant to characterize reverse logistics (Fleischmann et al., 1997). De Brito and Dekker (2002) provide typologies of the what, whom and how of reverse logistics, which we adapted to fill out the tables in Appendix B. In short,

Return reason typology:

- Manufacturing returns (raw material surplus, quality-control returns and production leftovers);
- Distribution returns (product recalls, B2B commercial returns, stock adjustments and distribution items/functional returns);
- (Pos-)Market returns (B2C commercial/reimbursement returns, warranties, service returns/repairs and spare parts, end-of-use, end-of-life returns.

Driving force typology:

- Economics (direct profit and indirect –competition, green image, legislation's anticipation, etc.)
- Legislation
- (Extended) Responsibility (public, social, environmental, etc.)

Recovery option typology:

- Direct recovery (re-sale/re-use/re-distribution
- Process recovery (repair, refurbishing, remanufacturing, (parts) retrieval, recycling, incineration and (proper) disposal.

We present the case studies according to the following decision-making focus: Reverse Logistics Network Structure, Relationships, Inventory Management, and Planning and Control (see Ganeshan et all, 1999; Fleischmann et al, 1997). Furthermore, we give an

overview of Information and Technology (IT) for reverse logistics. By IT we denote technological means to process and transmit information (see IT definitions by OECD and NAICS, electronic references). If a case focuses on multiple decisions, we discuss it in more than one section.

3. Statistics

We have found more than sixty cases involving reverse logistics. Using the United Nations classifications for Industry (see http://esa.un.org), 60% of the cases are in the manufacturing category; about 20% are within wholesale and retail trade and about 10% in construction. We have also found cases in the following categories: transport and communication, public administration and defense, and other community services. Grouping with respect to products (see http://esa.un.org), we observe that almost half of the cases deal with metal products, machinery and equipment. Around 30% of the products being processed are transportable goods like wood, paper and plastic products. Around 20% concern food, beverages, tobaccos, textiles and apparel. Less than 10% fell in the category ores and minerals. Not surprisingly, these numbers show that the majority of the cases are on products with high value. The majority of the cases are from Europe. In fact, we report on 1 case from South America, 2 cases from Asia, 14 cases from North America and more than 50 cases from Europe (note that some cases relate to more than one geographic area). The unequal distribution of cases over geographic areas corresponds to the unequal past development of reverse logistics research in the different continents.

4. Case studies on Reverse Logistics Network Structures

Main activities in reverse logistics are the collection of the products to be recovered and the redistribution of the processed goods. We found 24 case studies on this subject (see Appendix, Table B.1). The most often described recovery option was recycling (11 cases), next re-use/redistribution (10 cases of which 7 described in De Koster et al., 2001), two on remanufacturing and one on repairs. The cases on re-use can be split up into the handling of commercial returns at retailers and the ones on distribution items such as bottles, crates and containers.

Observations

Obs. 1: The critical issues for distribution items are the determination of the number of items needed and the efficient redistribution, i.e. making sure that companies receive the right amount of items at the right moments in time with as little transportation as possible (see Kroon and Vrijens, 1995 and Duhaime et al., 2001).

Obs. 2: Critical issues for remanufacturing are the location of the remanufacturing facility, how to ensure a sustainable volume of products to be remanufactured and finally, how to reduce the uncertainty in the supply of cores (products to be remanufactured). (See also Fleischmann et al., 2001; Guide, 2000; Guide et al., 2000 and Guide and van Wassenhove, 2001)

Obs. 3: – Recycling:

- Both private and public networks exist, although several private ones were not successful (see e.g. the initiatives on carpet recycling, Louwers et al., 1999; Realff et al., 2000 and the ending in AFX-NL 30 Aug 2001)**.** The public networks were created out of government interference in order to reduce waste.
- Environmental objectives are prime reason and costs are second in public networks and the other way around in private networks. The first is often financed through a upfront fee on new products for recycling.
- Recycling often requires expensive facilities and therefore is likely to be centralized. In order to be economically viable, sufficient volumes should be realized (Spengler, 1997; van Burik, 1998; van Notten, 2000). Accordingly, much transportation is needed (see Anderson et al., 1999)

Propositions and Research opportunities

Prop.: Product acquisition and collection network efficiency are major bottlenecks in the economics for private recycling networks, which are therefore more likely to fail than public networks.

Res. Opp. 1: Time, quantity and quality uncertainty in acquisition are known critical factors for reverse logistics (see Fleischmann et al., 1997). We believe that these uncertainties are the explaining factor for public recycling networks subsisting while private ones do not. We suggest an extensive comparative analysis of cases or a survey analysis to test the proposition.

Res. Opp. 2 Economies of scale are needed for successful recycling, inevitably increasing transportation. The trade-off between the environmental benefits of recycling versus the extra

transportation has not been established yet. To do so it is preferable to bring together both economic and ecological (eco-eco) aspects. Some eco-eco models are available (see Bloemhof-Ruwaard et al., 2003).

5. Case Studies on Reverse Logistics Relationships

Typical for reverse logistics is that several parties are involved like the sender of the product, the collector, the processor and the initiator. To stimulate/enforce a certain behavior of their partners, parties in the reverse chain may make use of varied incentive tools. In this subsection we will discuss our findings with respect to the tools that are used in practice to stimulate/enforce a desired behavior of partners in the context of product recovery. A summary of all cases found is provided in Table B.2.

Observations

Obs. 1: There are quite a lot of different tools in the literature: *1) Refund options* (Tsay, 2001); *2) Buy back options* (www.ford.nl); *3) Fees* (Faria deAlmeida and Robertson, 1995; Bartel, 1995); *4) Take back* (Wijshof, 1997); *5) Trade-in* (Driesch et al, 1998); *6) Lease or rent contracts* (Sterman, 2000); *7) Bring-pick up systems* (Bartel,1995; McGavis, 1994; Yender, 1998; Guide and van Wassenhove, 2000); *8) Timely and clear information* (Faria deAlmeida and Robertson, 1995); *9) Power* (Farrow and Johnson, 2000); *10) Environmental responsibility* (McGavis,1994); *11) Social responsibility* (McGavis, 1994), and *12) Acquisition price* (Guide and van Wassenhove, 2001).

Obs. 2: Almost all the case studies that we have found describe tools for stimulating acquisition of goods for recovery. Only one example (Farrow and Johnson, 2000) deals with the enforcement of take back.

Obs. 3: Some tools make up part of sales contracts, like the buy back option offered by Ford (www.ford.nl). Other tools like trade-ins require the customer to buy another product in exchange, like is the case of the engine trade-in option offered by Daimler Chrysler (Driesch et al, 1998). There are also tools that are not directly coupled to a selling activity like a gift to a non-profit organization as used by Hewlett Packard for getting back toner cartridges (McGavis, 1994), or as recently used by TESCO to get back mobile phones (see www.tesco.com).

Obs. 4: We did not find cases on deposit fees (fees paid upfront fully reimbursed upon return, e.g. on beer crates).

Obs. 5: Most case studies describe the tools that are used, without explaining why that tool has been chosen and how the values of parameters related to that tool have been determined.

Propositions and Research opportunities

Prop.: Only deposit fees and buy back options for used products are specific for product recovery. The other mentioned tools are also used to attract customers in general.

Res. Opp.: When to use which (combination of) tool(s) to achieve desired collection goals (quantity, time, quality)?

There is literature available dealing with one or more aspects of those mentioned above. For instance, 1) literature on sales contracts with return options for unused products (see Tsay, 2001; Anupindi and Bassok, 1999; Corbett and Tang, 1999; Lariviere, 1999; Tsay et al.,1999); 2) research on the optimal acquisition price (fee) to realize a certain flow of products (e.g. Klausner and Hendrickson, 2000; Guide et al, 2001; Guide and van Wassenhove, 2001); 3) optimal picking frequencies to achieve a certain collected quantity (Tucker et al., 2000). This literature can be used as a starting point for deriving models to answer the above general question.

6. Case studies on Inventory Management

Fourteen cases on inventory management within reverse logistics were found (see Appendix, Table B.3). We found cases related to commercial returns, distribution items, service returns (repairs), end-of-use, and end-of-life returns (see De Brito and Dekker, 2002 for a discussion of the return reasons typology).

Observations

Obs. 1: Commercial returns (reimbursement)

From the cases it appears that the inventory issues are twofold, first what should happen with the returned item and secondly how is the reordering influenced by the returns. In case of commercial returns, the items are usually of almost as good as new quality; hence in Europe they can often be included into inventory after a simple inspection (see De Brito and Dekker, 2003). In the US laws prohibit selling sold products as new and other recovery actions need to be taken. If the products that are returned can be resold it is important to know the return rate and the return time lag. These aspects are especially important in case of seasonal or non-stationary demands where the determination of the amount needed in a certain period is the crucial issue.

Obs. 2: Service returns (repairs)

The cases have the following characteristics: the repair chain is considered as a closed loop often with multiple echelons. It is important to determine how many parts are needed at each stocking location and how much repair capacity there should be in order to guarantee availability. Time is critical. This area has been studied for long without making the connections with reverse logistics. For an overview we refer to Guide and Srivastava, 1997b.

Obs. 3: Distribution items

Distribution items like containers, bottles, pallets, crates are used in the distribution of other items. From the cases it appears that the main issue is the match between returns and demands in time and place. How much are needed at which location and how much should be relocated within a certain time interval. Most items issued come back, but it is not always known when.

Obs. 4 End-of-use/life returns

End-of-use / life items can be used for spare parts recovery as described in two cases (Fleischmann (2000) and Klausner and Hendrickson (2000). Essential is to know the exact composition and state of returns, as well as their moment of return.

Propositions and Research Opportunities

Prop. 1: To improve the knowledge on what can be recovered from returns is the critical factor for an efficient and effective recovery at part or product level.

Res. Opp.: To determine quality, ease of disassembly and demand from parts / products as function of their state in the product life cycle. To do so, the existent forecasting techniques have to be enriched with broader explanatory variables. For instance, it is increasingly common that retailers and others collect considerable amounts of data on their customers. Thus, a categorization of customers is conceivable and to include that variable in forecasting models should be the next step. We refer to Toktay (2003) for a discussion of other factors influencing returns, which are potential explanatory variables in wise forecasting models.

7. Case studies on Planning & control of recovery activities

This subsection deals with the planning and control of the recovery activities, i.e. the actual execution of recovery activities. The cases are succinctly presented in Table B.4.

Observations

Obs. 1: The case studies on planning and control of product recovery activities that we found in literature can be subdivided into case studies dealing with: *1*) *the separate collection of (parts of) products for recovery* (Andriesse, 1999; Del Castillo and Cochran, 1996; Duhaime et al, 2001; Klausner and Hendrickson, 2000; Bartels, 1998; Van Donk, 1999; Van Notten, 2000; Schinkel, 2000; 't Slot and Ploos van Amstel, 1999; Ubbens, 2000 and Wijshof, 1997; *2) the separate processing of (parts of) products for reuse or disposal* (Bentley et al, 1986; Robison, 1992; Guide and Spencer, 1997; Guide and Srivastava, 1997a; Guide et al., 1997; Guide and Srivastava, 1998; Thomas Jr, 1997; Spengler et al, 1997); *3) the combined planning and control of collection of products for recovery and distribution of new products:* (Simons, 1998;Bakkers and Ploos van Amstel Jr, 2000); and *4) the combined planning and control of processing products for recovery and production of new products* (Gupta and Chakraborty, 1984; Teunter et al, 2000).

Obs. 2: In many of the case studies that we found, one or more planning and control issues are very globally described. The descriptions of the planning and control concept or the (quantitative) motivation behind it are hardly ever given.

Obs. 3: The case studies offer practically no insight into the problems companies have with the planning and control of their product recovery activities, nor in the results obtained with their planning and control concept.

Obs. 4: All cases concern the recovery of autonomously supplied products.

Propositions and Research Opportunities

Prop. 1: The planning and control concepts for product recovery do not differ from the planning and control concepts used in other areas.

Prop. 2: The planning and control of product recovery is more complex than the planning and control of forward production and distribution.

Res. Opp.1: To test the above hypotheses, first one has to identify, analyse and evaluate the performance of the planning and control concepts that are being used in practice. This can be achieved through comparative case study research. We suggest multiple case studies per type of planning and control systems (Obs. 1), among which cases dealing with commercial returns (Obs. 4). The research can be carried out in three phases: 1) to identify the planning and control concept that the company uses; 2) to assess how the values of parameters are calculated; 3) to develop performance measures and to assess performance. Another possible approach is survey analysis. Specific studies are already available. Nasr et al. (1998) and

Guide (2000) and investigated the industry practice concerning the production planning and control for remanufacturing in the United States.

Res. Opp.2: To rate the practicability of theoretical planning and control concepts.

Quite a number of planning and control concepts for product recovery have been presented in academic literature. However, the supply of recoverables is often assumed to be autonomous, except for some literature on repair (for an overview see e.g. Guide and Srivastava, 1997b) and remanufacturing (see Guide, 2000; Guide et al., 2001; Guide and van Wassenhove, 2001; Minner and Kiesmuller, 2002). No direct relation between sold/leased and recovered products is assumed. Besides this, uncertainty has been incorporated only as far as the arrival of products for recovery and the duration of repair related activities are concerned. Uncertainty with respect to the result of the processing activities has hardly been taken into account (for an exception, see Souza et al, 2002)

8. Case studies on IT for Reverse Logistics

We have found various cases concentrating on applications of IT for reverse logistics activities (see Table B.5). IT is used to support reverse logistics during different stages of the life cycle of a product, namely product development, (re-)distribution and market (see Kokkinaki et al., 2003 and Hendrickson et al, 2003). Table I presents the IT tools, requirements and benefits for reverse logistics identified in the case studies that we found.

IT Tool	Information's requirements	Type of support	Life cycle phase
EDL for electric motors reuse (Klausner et al., 1998) , (Klausner and Hendrickson, 2000)	(Info. on potential cost savings)	Reuse decisions through information on usage pattenrs	Product development; Market
DSS for end-of-use; (Nagel and Meyer, 1999)	Info. on operations' costs & recycling revenues	Cost optimization, facilities location, vehicle routing, etc.	(Re-)distribution
Computer's configuration reader (Nagel and Meyer, 1999)	Info. on operations' costs & recycling revenues	Setting buy-back price;	Market
Software specialized on return handling (Meyer, 1999)	Product's expiration data, damage check	Recovery-related decisions	(Re-)distribution
DSS for remanufacturing (Linton and Jonhson, 2000)	In-depth information on processes	Remanufacturing-related decisions	(Re-)distribution
DfX, remote maintenance, etc. (Maslennikova & Foley, 2000)	Extensive data-base on products	Recovery options, environment's sustainability, and so forth.	All phases
DfX (X=Recyclability) (Farrow and Jonhson, 2000)	Further separation of resins; Technological innovation;	Developing a 100% recycled (& recyclable) Kayak.	(Re-)distribution

Table I. IT tools, requirements and benefits for reverse logistics, per case study.

Observations

Obs. 1: The case studies illustrate IT applications in all the phases of the life cycle of a product and show improvements for reverse logistics (see Table I). E.g., Xerox (Maslennikova and Foley, 2000) has an integrated solution for reverse logistics from product development to recovery or proper disposal.

Obs. 2: All the case studies provide in one way or another an evaluation on the benefits of IT. However, the investments on such technologies or on the gathering of information are not reported, except for the Estée Lauder case (Meyer, 1999) and partially for Walden Paddlers (Farrow and Jonhson, 2000). Besides this, none of the studies relate to costs associated with the management of information and so on.

Obs. 3: The IT tools to support reverse logistics are very demanding regarding data on the processes, costs and earnings (see Table I).

Propositions and Research opportunities

Prop.: Data rather than technology is the limiting factor for the use of IT for Reverse Logistics.

Though the technology is available, IT tools are very demanding regarding data on reverse logistic processes and associated costs and earnings. This data is however often not available. Nagel and Meyer (1999) declare that the lack of information is a bottleneck, which complicates the management of recycling systems. Furthermore, on the Nortel Networks case the DSS could not be designed as desired due to a shortage of data on customer's returns (see Nagel and Meyer, 1999).

Res. Opp. 1: To test the validity of the previous proposition. To begin with, one has to determine what are the costs and benefits related to reverse logistics processes. The cases indicate that there is no broad knowledge on the costs associated with reverse logistics processes, neither on the worth (see e.g. Nagel and Meyer, 1999). A plausible way of starting is to pursue case studies with the purpose of giving an empirical range of values for cost and profit parameters.

Res. Opp. 2: To identify high impact IT tools for reverse logistics through the whole product life cycle.

As remarked before, the case studies stress the benefits while the investments are neglected. There are some studies investigating the benefit of data logger technology (Klausner et al., 1998; Simon et al., 2001). The same can be done for all the other supportive IT tools. We observe that IT tools employed in a product life phase are individually beneficial. In face of limited investment capacity, it would be helpful to know in which phase the investment

would have most earnings. In addition, if alternative technologies are available, one can investigate which one is the best. To do so, one has to take into account: costs and benefits of collecting and managing data and costs of investing and managing the technology. The following literature is an excellent starting point, as the potential advantages or bottlenecks of some type of information are partially analyzed: Kelle and Silver (1989), Inderfurth et al. (1999), De Brito and Van der Laan (2002), Ferrer (2003), Kiesmuller (2003), and Toktay (2003).

9. Summary and conclusions

We have provided a content analysis of more than 60 cases reported in the literature dealing with reverse logistics aspects. We also have given an overview of particular issues per section, which we have linked to propositions and research opportunities.

In this way, 1) we have given a fair idea of the diversity of real life reverse logistics situations; 2) we have provided a reference guide to researchers searching for case support; 3) besides proposing specific directions for future research, we have handed over a check list tool for researchers willing to conduct (comparative) case studies (e.g. by looking after issues not well investigated yet).

The majority of the case studies deal with one aspect of a real reverse logistics situation but they do not give the overall business environment, what make insights sort of one-dimensional. Thus, there is a need for conducting more integral case study research, by mapping the business context together with more broad information on critical factors, trade-offs and implications.

By comparing North American with European cases, one notices that the prime driver in most North American cases is economics while in Europe legislation is also an important driver. For researchers acquainted with practice, this is a well-known ‘truth.’ However, there is room to investigate to which degree this difference in drivers makes the differences, or not, in network structures, relationships, inventory management and planning and control. Or instead, to directly investigate whether to some businesses similarities are a function of the industry. This could not be established with this content analysis, as the collection of the case studies have been disparately conducted. We suggest sampling groups of cases with different drivers and industry categories and to proceed to an intra- and inter- case study comparative analysis.

Finally we have observed a lack of cases on reimbursement returns. However, with the growth of the catalogue industry (also in the Internet), this is an area with a challenging reverse logistics problematic, which calls for field research.

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Appendix A – Keywords

The search was executed with each of the words from Table A.1 and (a combination of) the words: logistics, planning, control, transport, inventory, capacity, production, information.

Asset recovery		
By-products/byproducts	Post-consumer	Repair
Containers	Producer responsibility	Repairable
Co-products/co-products	Product ownership	Resale / re-sale
Core	Product recovery	Resell / re-sell
Defects	Product stewardship	Return (includes commercial
Defective	Reassembly	returns)
Disassembly	Rebuild	Reuse/ re-use
Dismantling	Recalls	Reutilisation
Disposal	Reclaim	Reusable
Downgrading	Reclamation	Reverse logistics
Energy recovery	Reconditioning	Rework
Environment	Re-consumption	Salvage
Garbage	Recovery (product, resource,	Secondary (market, materials)
Gate keeping	asset)	Separation
Green logistics	Recycling	Source reduction
Material recovery	Refill	Take back
Obsolete (stock)	Refillable	Upgrading
Outlet	Refurbishing	Value recovery
Overstock	Remanufacturing	Warranty
	Repack	Waste

Table A.1 Search words.

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Appendix B – The case studies: supply chain and recovery overview

Network structure

	Product			Supply chain					Return reason and /or Drivers	
Reference	**Product (in)**	**Process**	**Product (out)**	**Sender**	**Collector**	**Processor**	**Customer**	**Initiator**	**Sender**	**Initiator**
Barros et al. (1998)	construction waste	recycling	Sand	waste processors	consortium	consortium	construction industry	consortium	end-of-life (waste disposal)	legislation
Bartels (1998)	batteries	recycling	Materials	households, Companies	municipalities, Retailer chains, Schools	specialized companies		Ducth master organization of importers of batteries	end-of-use (environmental responsibility, small presents)	legislation
Chang et al. (2000)	household waste	recycling		households	public authority: environmental protection bureau	public authority: environmental protection bureau		Kaohsiung's city government	end-of-life (waste disposal)	(public) responsibility
DelCastillo & Cochran (1996)	See Table on Inventory Management (B.3)									
De Koster et al. (2000)	large white goods	recycling	Materials	households	municipalities, retailers, 3rd party logistics service providers	recycling companies (CoolRec, HKS)	materials processing companies	Dutch organizations of electronics supply chain	end-of-life (no disposal costs)	legislation
De Koster et al. (2001)	products, packaging materials, distribution items	re-distribution (sorting, re-stocking)	same product packaging and distribution items, and waste	individual supermarkets	Supermarket chain / Distribution Centers	supermarket A	supermarkets, materials collectors, processors, suppliers	Supermarket A	functional, commercial & end-of-life (less disposal costs)	economics (less disposal costs)
De Koster et al. (2001)	shoes, sports attributes, waste, advertisement materials	re-distribution (sorting, re-stocking)	same product, packaging and distribution items, and waste	customers / chain stores	chain stores / Distribution Centers	chain store A	same & other market (special outlets)	chain store A	reimbursement	economics
De Koster et al. (2001)	products, coat hangers and racks	re-distribution (sorting, re-stocking)	same product, waste, reusable containers, coat hangers	Customers / chain stores	chain stores / DC	chain store B	same & other market (special outlets)	chain store B	reimbursement	economics
De Koster et al. (2001)	products / advertisement materials / containers	re-distribution (sorting, re-stocking)	same product, waste, reusable containers, coat hangers	customers / chain stores	chain stores / DCs	chain store C	same & other market (special outlets)	chain store C	reimbursement	economics
De Koster et al. (2001)	consumer goods	re-distribution (sorting, re-stocking)	same product	customers	mail order company A	mail order company A	same market	mail order company A	reimbursement	economics, legislation (business requirement)
De Koster et al. (2001)	consumer goods	re-distribution (sorting, re-stocking)	same product	customers	distribution centers	mail order company B	same market	mail order company B	reimbursement	economics, legislation (business requirement)

De Koster et al. (2001)	cloths, small appliances	re-distribution (sorting, re-stocking)	same product	customers	distribution center	mail order company C	same market	mail order company C	reimbursement	economics, legislation (business requirement)
Dijkhuizen (1997)	defective parts	remanufacturing	remanufactured parts	Customer	regional or national center	regional or national center	same customer	IBM	service returns	economics (market protection, feedback on quality) Legislation
Duhaime et al. (2001)	Distribution items	re-distribution (cleaning)	same product	Canada Post	Canada Post	Canada Post	Canada Post	Canada Post	functional returns	economics
Kleineidam et al. (2000)	wastepaper	recycling vs. incineration	Paper material or energy	households, businesses	mainly non-profit organisations	wastepaper processor vs. collector	pulp industry		end-of-life (waste disposal)	economics
Kroon and Vrijens (1995)	Distribution items	re-distribution (cleaning)	same product	business customers	Nedlloyd	Nedlloyd	business customers		functional (incentive: deposit fee)	economics (rental income)
Krikke (1999a)	used photocopiers	remanufacturing	remanufactured photocopiers	Local operating company	Oce, a copier firm in NL or (Czech Rep.)	Oce	Same & New Market	Oce	end-of-use (incentive: fee)	economics
Louwers et al. (1999)	carpets	recycling	fibers, filling materials for roads and dams etc	households, companies (e.g. involved in floor covering)	companies involved in floor covering, municipalities, special organization	organization for sorting, fiber producers, cement industry	customers for fibers, cement, road and dam builders	carpet industry, including their fiber suppliers	end-of-use/ end-of-life	economics (image); legislation, (expected)
Meijer (1998)	scanners,faxes, printers, copiers, tonercartridges packaging	remanufacturing recycling	remanufactured machines, materials;	households, companies	dealers, Third party logistics service providers	Canon France (Toner Cartdr.), Canon Scotland (Copiers)	Canon	Canon	end-of-use/ end-of-life (incentive: no disposal costs)	economics (green image)
Realff et al. (2000)	Carpeting Mat.	recycling	nylon fibres	business customers	carpet dealers	DuPont		DuPont	end-of-life (waste disposal)	economics (market value)
Spengler (1997)	steel by-products	recycling	materials	steel industry	steel industry	steel industry	steel and other industry	industry, government	manufacturing (leftovers); disposal/ cost savings	public responsibility
Idem	domestic buildings	recycling	materials	households	demolition companies	recycler	industry	government	end-of-life (disposal/ cost savings)	public responsibility
Van Burik (1998)	car wrecks	recycling	materials, waste	car owner	certified disassembly companies	selected recycle companies		car importers in The Netherlands	end-of-life (incentive: no disposal costs)	legislation, economics
Van Notten (2000)	glass from bottles, pots	recycling	materials (input for glass industry)	households, companies	specialized companies	glass recycling companies	glass industry	glass collectors, glass recyclers, glass producers	end-of-life (incentive: no disposal costs)	legislation

Table B.1: Case studies with focus on Network Structures.

Relationships

	Product			Supply chain					Return reason & Drivers	
Reference	**Product (in)**	**Process**	**Product (out)**	**Sender/Giver**	**Collector**	**Processor**	**Customer**	**Initiator**	**Sender**	**Initiator**
Bartel (1995)	toner cartridge	remanufacturing (parts) retrieval	remanufactured toner cartridges , or parts	customers of Unisys	US postal services		Customers of Unisys	Unisys	end-of-use (fee as an extra incentive)	economics (to offer recovered toner cartridges)
Driesch et al. (1998)	car engines	remanufacturing refurbishing	same product	owners of a Mercedes Benz (MB) car with an MB engine	MB dealers	DR MTR	owner of a MB car	Daimler-Chrysler (Mercedes-Benz)	service	economics (customer's relations)
Faria de Almeida and Robertson (1995)	batteries	recycling	materials	user batteries	shopping malls, stores, mobile collection units recycling points	different processors	customers raw materials	City of Leicester (UK)	end-of-use	
Farrow and Jonhson (2000)	See Table on Information Technology (B.5)									
Guide and van Wassenhove (2000)	toner cartridge	remanufacturing	remanufactured or recycled toner cartridges	customers of Xerox	US Postal Services		same chain (customers of Xerox)	Xerox	end-of-use returns (fee as an extra incentive)	economics
Guide and van Wassenhove (2001)	cellular phones	remanufacturing (testing, sorting)	same product	cellular airtime providers	Recellular, 3rd party remanufacturer	Recellular				economics
McGavis (1994)	used toner cartridges	recycling	materials	user cartridge	UPS	several processors for different parts	HP	HP	end-of-use returns (donation by HP to WWF as an incentive)	economics (energy savings, bad image by bad quality 3P remanufacturer)
Vroom et al. (2001)	PC bottles; distribution items (crates, pallets)	re-distribution (cleaning, sorting)	same product	households; supermarket.; DCs supermarket chains;	supermarket; supermarket chains and DC's; Campina;	Campina	Campina	Campina	end-of-use returns (deposit fees as an incentive) functional returns	economics
Wijshof (1997)	Rock wool from building or demolishing locations	recycling (also cleaning)	material (secondary input production rock wool)	building companies, demolishers, rock wool sellers	third party logistics service provider (BFI, Sovabo)	sorting by BFI or Sovabo; recycling by Rockwool	building industry	Rockwool	end-of-life (less disposal costs as a natural incentive)	economics (green image)
Yender (98)	batteries	recycling, (also recharging)	raw materials, batteries	households, companies	UPS, retailers, municipalities	different processors including INMETCO	raw materials users	rechargeable battery recycling corporation	end-of-use	

Table B.2: Case studies with focus on Relationships.

Inventory Management

	Product			Supply chain					Return Reason & Drivers	
Reference	**Product (in)**	**Process**	**Product (out)**	**Sender**	**Collector**	**Processor**	**Customer**	**Initiator**	**Sender**	**Initiator**
De Brito and Dekker (2003)	laboratory equipment (15 000 sku)	re-use (refunding and re-stocking)	same product	internal customers	Customer brings it back	CERN	internal customers	CERN	commercial returns (reimbursement)	economics
De Brito and Dekker (2003)	fashion, electronics and furniture	re-distribution (collection, inspection, re-stocking)	same product	customers	mail-order-company	mail-order-company	customers (same chain)	mail-order-company	commercial returns (reimbursement)	economics (marketing) legislation
De Brito and Dekker (2003)	thousands of spare parts	repair and/or re-stocking	same product	maintenance personnel	maintenance brings it back	refinery (as maintenance)	internal customers		commercial returns (no longer needed)	economics
DelCastillo and Cochran (1996)	softdrink bottles	re-distribution (cleaning)	same product	consumer	retailers	Coca Cola	original chain	Coca Cola	end-of-use (plus deposit)	economics (cost savings)
Diaz and Fu (1997)	railway spare parts	repair	repaired spare parts	Caracas Subway	Caracas Subway	Caracas Subway	Caracas Subway	Caracas Subway	repair	economics (cost savings)
Donker and van der Ploeg (2001)	circuit boards for telephone-exchanges	repair	repaired circuit boards	telephone companies	Lucent Technologies	Lucent Technologies	telephone companies	Lucent Technologies	repair	economics (cost savings)
Fleischmann (2000)	used/ unused machines	repair/ refurbishment (dismantling)	spare parts	business customers,/ retailers		IBM facilities			commercial (overstocks/ no longer needed)	economics / legislation
Klausner and Hendrickson (2000)	power tools	remanufacturing recycling	Remanufactured power tools, or materials	customers	dealer, logistics provider	specialized facility		manufacturers of power tools	end-of-use	economics (pro-active policy)
Moffat (1992)	aircraft engine	repair, refurbishing	re-processed aircraft engine	UK Air force	UK Air force	UK Air force	UK Air force	UK Air force	service returns (repairs)	economics (cost savings)
Rudi et al. (2000)	wheel chairs, hearing aids, etc	reuse/ refurbish/ recycling/ retrieval, landfill	re-processed wheel chairs, hearing aids, etc.	users	Technical Aid Center (TAC)	TAC (in some cases recycling center)	people with handicaps	Norwegian National Insurance Administration	service returns (repairs) end-of-use returns	economics responsibility
Sanders et al. (2000)	complete products retail	re-distribution (collection, sorting)	same product	customer	third party logistics service provider	Mail Order Company, Wehkamp	Same market	Wehkamp	commercial return (reimbursement)	economics (to attract and keep customers)
Swinkels and van Esch (1998)	Beer kegs	re-distribution/ re-use	same product	restaurants, bars, etc.	Bavaria, Agents	Bavaria	Bavaria	Bavaria	functional returns (distribution item)	economics (cost savings)
Toktay et al. (2000)	single-use photo cameras	remanufacturing	same product	consumer	Photo Shops / Retailers	Kodak	Same chain	Kodak	end-of-use (or distribution item)	economics (cost savings)
Van der Laan (1997)	used car parts	remanufacturing	same product	National Importer Organization	Volkswagen (Kasse'sl facility)	Kassel (remanufactur.)	NIO which delivers to car sellers	Volkswagen (Kassel's facility)	end-of-use	economics

Table B.3: Case studies with focus on the Inventory Management.

Planning and Control

	Product			Supply Chain					Return reason & Driver	
Reference	**Product (in)**	**Process**	**Product (out)**	**Sender/Giver**	**Collector**	**Processor**	**Customer**	**Initiator**	**Sender**	**Initiator**
Andriesse (1999)	pallets, pallet'scaps	re-distribution (sorting)	same product	suppliers	Philip Morris	Philip Morris	suppliers	Philip Morris	functional (plus cost reduction)	legislation
Bakkers and Ploos van Amstel Jr . (2000)	PVC lamellas	recycling	PVC material	Households, companies	Distributors lamellas	Ortes Lecluyse	Ortes Lecluyse	Ortes Lecluyse	end-of-life (plus no disposal costs)	economics (green image
Bartels (1998)	See Network Structure Table (B.1)									
Bentley et al. (1986)	subway/transit cars	repair/ refurbishing (overhaul)	re-processed product	NY City , NJ, Chicago, Transit, etc		Morrison-Knudsen Company	NYCity , NJ, Chicago Transit, etc	Morrison-Knudsen Company		economics
Del Castillo and Cochran (96	**See Inventory Management Table (B.3**									
Duhaime et al. (2001)	See Network Structure Table (B.1)									
Driesch et al. (1998)	See Relationships Table (B.2)									
Guide and Spencer (1997); Guide et al (1997); Guide and Srivastava (1998)	aircraft, engines, avionics equipment	remanufacturing	remanufactured aircraft, engines, avionics equipment	Air force	Air force	US Navy overhaul/ repair Depot	Air force	Air force		
Gupta and Chakraborty (1994)	glass scrap	recycling	glass materials	Producer glass	Producer glass	Producer glass	Producer glass	Producer glass	manufacturing leftovers (plus savings)	economics (costs savings)
Klausner and Hendrickson (2000)	See Inventory Management Table (B.3)									
Krikke et al. (1999b)	PC monitors	(parts) retrieval, recycling	components materials	consumers	Municipal Waste Company		secondary markets	Municipal Waste Company in NL		legislation, economics
Robinson (1992)	Diesel engine components	remanufacturing	remanufactured engine components			Detroit Diesel remanufacturer West		Detroit Diesel remanufacturer West		
Schinkel (2000)	gypsum (building industry)	recycling (sorting)	gypsum	building companies	third party LSPo	producers of Gypsum products	customers producers Gypsum products	Producers of Gypsum products (organization)	end-of-life (lower disposal costs as an incentive)	legislation
Simons (1998)	wooden sheets, prod. scrap (internal and external)	recycling (sorting)	wood materials	Trespa (prod. scrap)/Scrap from building sites	third party LSP , builders, demolishers	Trespa	Builders	Trespa	manufacturing leftovers (plus reduction on disposal costs)	economics (green image), (expected) legislation

Simons (1998)	pallets	re-use (sorting, cleaning)	same product	builders, demolishers	third party LSP, builders, demolishers	Trespa	Trespa	Trespa		economics, legislation
Spengler et al. (1997)	See Network Structures Table (B.1)									
Teunter et al. (2000)	by-products	re-use (after refurbishing)	pharmaceutical materials	(manufacturing process)		Schering AG (pharmaceutical company)	(manufacturing process)	Schering AG	manufacturing returns (by-product)	
't Slot and Ploos (1999)	white and brown goods	recycling	reusable materials	households	municipalities, retailers	recycler	users materials	government	end-of-life (incentive: no disposal costs)	responsibility
Thomas Jr (1997)	aircraft	remanufacturing	airplane engines				Pratt & Hitney aircraft West Virginia	Pratt & Hitney aircraft West Virginia		
Ubbens ('00)	tin plate containers for beverages, food etc	recycling	tin materials	households etc	municipalities (via household waste)	household / metal waste processing companies	Metal industries	Stichting Blik		legislation
Van Donk (1999)	leftovers from building activities	recycling		buidling companies	special collectors				manufacturing leftovers (plus lower disposal costs)	responsibility, legislation
Van Notten (2000)	See Table on Network Structures (B.1)									
Wijshof (1997)										

Table B.4: Case studies with focus on Planning and Control

Information Technology

	Product			**Supply chain**					**Return reason & Driver**	
Reference	**Product (in)**	**Process**	**Product (out)**	**Sender/Giver**	**Collector**	**Processor**	**Customer**	**Initiator**	**Sender**	**Initiator**
Nagel and Meyer (1999)	refrigerators	remanufacturing recycling	plastics; metals;	end-of-life user	dealer; service provider	recycling plant			end-of-life	legislation, economics
Idem	computers	(parts) retrieval	C omputer components	End-of-life user	VOBIS (retailer)	Covertronic (Recycler)		Covertronic (Recycler)	end-of-life	economics
Meyer (1999)	cosmetics	re-sale (re-stocking)	cosmetics	customer	Estee Lauder	Estee Lauder	(same chain or employees)	Esteé Lauder	reimbursement	legislation, economics
Farrow and Jonhson (2000)	post-consumer & other plastics	recycling (DfX, innovation),	(100% recycled) Kayak	consumer	supplier of recycled resins	kayak's manufacturer	from the recreational Kayak Market	Walden Paddlers, Inc.	end-of-life (waste disposal)	responsibility
Linton and Jonhson (2000)	circuit boards	remanufacturing	circuit boards	customer	customer Service (NN)	customer Service (NN)	(close-loop)	Nortel Networks	commercial returns	economics
Klausner et al. (1998, 2000)	See Inventory Management Table (B.3)									
Maslennikova and Foley (2000)	recycled materials; Xerox products	refurbishing, recycling (including DfX)	re-processed Xerox products	customer	Xerox Europe, Ltd. Service engineers	Xerox Europe, Ltd.	(same chain)	Xerox Europe, Ltd.	end-of-use (no longer needed)	economics, legislation

Table B.5: Case studies with focus on Information and Technology.

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ERIM Research Program: "Business Processes, Logistics and Information Systems"

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Hennie Daniels and Bram de Jonge
ERS-2003-001-LIS

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Hennie Daniels and Han van Dissel
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Ş. İl. Birbil, S.-C. Fang, J.B.G. Frenk and S. Zhang
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Marisa P. de Brito, Rommert Dekker, Simme D.P. Flapper
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Marisa P. de Brito, M. (René) B. M. de Koster
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