Reverse Logistics – a framework

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Abstract

In this paper we define and compare Reverse Logistics definitions. We start by giving an understanding framework of Reverse Logistics: the why-what-how. By this means, we put in context the driving forces for Reverse Logistics, a typology of return reasons, a classification of products, processes and actors. In addition we provide a decision framework for Reverse Logistics and we present it according to long, medium and short -term decisions, i.e. strategic-tactic-operational decisions.

Keywords: Reverse Logistics, Framework, decision-making, theory building.

1. Introduction

Reverse Logistics concerns activities associated with the handling and management of equipment, products, components, materials or even entire technical systems to be recovered (for succinctness we will often use the term products alone). Recovery can simply be just reselling a product. Or, it can be accompanied by a series of processes as collection, inspection, separation, and so on, leading to e.g. remanufacturing or recycling. Material recapture and product or equipment (partial) reuse is a very old practice. In the past, the primary motivation was scarcity of resources. However, the emergence of cheap materials and advanced technology led Western societies into mass consumption and routine throw away. By then, environmental matters or sustainable development were not objects of concern. In the early seventies however, the study for the Club of Rome augured that there was a limit to the growth. The report announced that around 2050 Mankind was going to disintegrate (Meadows, 1974) drawing attention to the need of sustaining the course of civilization. During the following decade environmental disasters kept the mind of the academicians, politicians, the media, and society in general addressed to such issues. Terms like recycling, reuse, resource reduction, environmental manufacturing responsibility and green products began to be familiar to all of us. Since the mid-nineties and especially in Europe this was accompanied with legal enforcement of product and material recovery or proper disposal. Also in the US landfill tolls became a lot more expensive and restrictions on cross-State transport of waste rose substantially. More recently, real examples like the remanufacturing of mobile phones have pointed out the profitability of recovery activities and its value-creation rather then environmental aspects (Guide and Wassenhove, 2001). In addition, competition, marketing or strategic arguments have pushed companies into generous return policies. Subsequently, as good as new returned products are re-distributed in the same market as it happens with catalog and e-tailer companies. Summarizing, more and more

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businesses and (non-)governmental organizations are being committed to material and product value recovery activities.

Accordingly, Reverse Logistics topics have increased in relevance both in practice and the academia (see e.g. Stock, 1992; Kopicky, 1993; Fleischmann et al., 1997; Rogers & Tibben-Lembke, 1998; Guide and van Wassenhove, 2001). In spite of all the literature dedicated to the Reverse Logistics, there is however a lack of theory development in the area of Reverse Logistics (see Dowlatshahi, 2000). Besides this, the few literature going in this direction exceeds on specificity, e.g. regarding a particular product or industry. In this paper we put forward a holistic decision framework for Reverse Logistics. In other words, we structure the decision process, not only by giving a typology of the problematic and associated decisions, but the inherent interrelations as well. The framework helps in understanding Reverse Logistics as a whole. We make primarily use of the knowledge created through the project RevLog (1998-), which included close interaction with related networks and businesses.The remainder of the paper is organized as follows. Next, we go into more detail regarding the scope of Reverse Logistics and we distinguish its domain as we relate it with other subjects like Green Logistics and Closed-Loop Supply Chains. Next, we provide a short review of the literature contributing to structure the Reverse Logistics field. After that we characterize Reverse Logistics by looking into it from three primary perspectives: why are there reverse flows, i.e. return reasons; what constitutes these reverse flows, i.e. which products and materials characteristics; and how can they be recovered, i.e. which are the intricate processes. Finally we put together a framework of decision-making for Reverse Logistics. We finish with some summarizing remarks.

2. Reverse Logistics: scope and delineation

" In the sweat of your face you shall eat bread
Till you return to the ground,
For out of it you were taken;
For dust you are,
And to dust you shall return." [1]
Genesis 3:19

Though the conception of Reverse Logistics dates from long time ago, the denomination of the term is difficult to trace with precision. Terms like Reverse Channels or Reverse Flow already appear in the scientific literature of the seventies, but consistently related with recycling (Guiltinan and Nwokoye, 1974; Ginter and Starling, 1978). The Council of Logistics Management (CLM) published the first known definition of Reverse Logistics in the early nineties (Stock, 1992):

"…the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal."

[1] New King James Version (see e.g. The Bible Gateway, a service of Gospelcom.net, http://bible.gospelcom.net/)

The previous definition is quite general, as it is evident from the following excerpts "the role of logistics in "and" all relating activities. In the same year Pohlen and Farris (1992) define Reverse Logistics, guided by marketing principles, as being:

"… the movement of goods from a consumer towards a producer in a channel of distribution."

Kopicky (1993) defines Reverse Logistics analogously to Stock (1992) but keeps, as previously introduced by Pohlen and Farris (1992), the sense of direction opposed to traditional distribution flows:

"Reverse Logistics is a broad term referring to the logistics management and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution (…) which causes goods and information to flow in the opposite direction of normal logistics activities."

In the end of the nineties, Rogers and Tibben-Lembke (1999) describe Reverse Logistics including the goal and the processes (the logistics) involved:

"The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal."

The European Working Group on Reverse Logistics, RevLog (1998-), puts forward the following definition:

"The process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point to a point of recovery or point of proper disposal"

The above definition is more extensive than the one proposed by Rogers and Tibben-Lemke (1999). We do not refer to "point of consumption" (overstocks are not to be consumed) nor do the products need to be returned to their origin, but may be returned to any point of recovery (e.g. collected computer chips do not go back to the original supply chain, but may enter another chain). In this way we incorporate more flows that naturally fit in the definition and which characteristics are the same as of other reverse logistic streams. At the same time we keep the essence of the definition as put forward by Rogers and Tibben-Lembke (1999), which is logistics.

Next to Reverse Logistics, there are several competing terms, like reversed logistics, return logistics and retro logistics or reverse distribution. In fact, the diversity of definitions with respect to recovery practices is a well-recognised source of misconceiving both in research as in practice (Melissen and De Ron, 1999).

While using the term Reverse Logistics, one is tempted to introduce the term forward logistics, to indicate all logistic activities on "virgin" materials and products. The difference however, is difficult to make as forward and reverse logistics melt in each other. New glass can well be made using a percentage of old glass. As a result the term "Closed-Loop Supply Chain" (CLSC) has been introduced, which received

popularity. It puts recovery practices in the frame of Supply Chain Management. It also stresses an encircling process, either 1) physical (closed-loop): original user; or 2) functional (closed-loop): original functionality. It can also be argued that this term puts Reverse Logistics in the frame of supply chain management and stresses that not only the reverse streams should be considered but also the integration with the forward streams. The draw back of the term CLSC is that quite often the streams/loops are not closed, but open. A more embracing term like simply Loop Supply Chain or Supply Chain Loop has been suggested by De Brito et al. (2002).

Reverse Logistics is different from Waste Management as the latter mainly refers to collecting and processing waste (products for which there is no new use) efficiently and effectively. The crux in this matter is the definition of waste. This is a major issue, as the term has severe legal consequences, e.g. it is often forbidden to import waste. Reverse Logistics concentrates on those streams where there is some value to be recovered and the outcomes enter a (new) supply chain.

Reverse Logistics also differs from Green Logistics as that considers environmental aspects to all logistics activities and concentrates specifically on forward logistics. Environmentally conscious manufacturing is a step further than just manufacturing for forward logistics. Long-run environmental impact is taken into account until the end-of-life of the product (see Gungor and Gupta, 1999).

Finally, reverse logistics can be seen as part of sustainable development. The latter has been defined by Brundland as "to meet the needs of the present without compromising the ability of future generations to meet their own needs." In fact one could regard reverse logistics as the implementation at the company level by making sure that society uses and re-uses both efficiently and effectively all the value which has been put in products.

3. Reverse Logistics: literature review on (related) theory building

We do not review established Reverse Logistics theory, simply because it is still in a process of formation. Instead, however, we review some literature adding to the theoretical growth of Reverse Logistics.

Thierry et al. (1995) shape product recovery management by detailedly going over the recovery options, from direct re-use to landfilling, and by situating them in the supply chain. In this paper besides outlining *how* products can be recovered, we add two dimensions that help to understand Reverse Logistics: *why* and *what*.

Fuller and Allen (1997) propose a typology of reverse channels, founded in the current practice of reverse logistics, specifically for post-consumer recyclable products. Thus, the paper is limited to a particular recovery option, i.e. recycling, and a particular source, i.e. households. Besides this, the focus of the typology is the listing of actors involved in recycling systems. We go behind this approach by considering a more extensive set of characteristics and overall recovery processes.

Carter and Ellram (1998) subdivide the literature on reverse logistics in, general, transportation and packaging, and purchasing. Then, they develop propositions by making use of marketing and management literature. Based on these, they put

together a model of the driving forces and constraints for Reverse Logistics. As the authors agree, the propositions lack empirical evidence. We identify Reverse Logistics features other than only driving forces and we accompany it with examples from real practice.

Gungor and Gupta (1999) present an extensive review of the literature (more than 300 articles or books) on environmentally conscious manufacturing and product recovery. They subdivide the literature in categories, outlining a framework. This paper looks upon product recovery from the point of view of environmentally conscious manufacturing. We contemplate a tri-fold driving force for Reverse Logistics: extended responsibility (where the environment accountability is included), economics and legislation.

Goggin & Browne (2000) have recently suggested a taxonomy of resource recovery specifically for end-of-life products with the focus on electronic and electrical equipment. The study is centered on a specific type of product namely, electronic and electrical equipment. Furthermore, only three types of recovery are taken into account. We keep our look upon Reverse Logistics thoroughly and not product specific.

Dowlatshahi (2000) classifies the literature on Reverse Logistics according to five categories: global concepts; quantitative models; distribution, warehousing, and transportation; company profiles; and, applications. In the opinion of the author the majority of the articles "lack of depth," "do not describe the basic structure of Reverse Logistics," and "do not define the basic concepts and terms." The author then gives attention to the literature and lists the strategic and operational factors in Reverse Logistics systems. After distinguishing the characteristics of Reverse Logistics, we put together a decision framework integrating a comprehensive list of strategic, tactic and operational matters.

From the previous review, one can notice limitations regarding generalizability. Papers had a too narrow focus. One can also observe that there is not one common classification of the spheres of the study of Reverse Logistics. This draws attention to the need of giving order to theory in this area. In contrast with the aforementioned literature, we do not focus in a single recovery option, or product, or in a specific driven factor.

4. Reverse Logistics: why, what and how?

After having briefly introduced the topic of Reverse Logistics, we go now in more detail by analyzing the topic from three main viewpoints: why, how and what. In previous literature, tiny excerpts of these viewpoints have been explored. This paper puts them all broadly together and in this way the fundamentals of Reverse Logistics are analyzed.

- Why are things returned: we go over the driving forces behind companies and institutions to become active in Reverse Logistics (at a high level and the reasons for reverse flows (return reasons);

- What is being returned: we describe product characteristics which makes recovery attractive or compulsory and give examples based on real cases;
- How Reverse Logistics works in practice: we list the actors and processes involved (how is value recovered from products);

Why (1): drivers behind Reverse Logistics

Reverse Logistics starts with products going back in the supply chain or calling for recovery or value reclaim. In principle there is a returning party, who had the product, and a receiving party, who is trying to resell, redistribute or recover value from the product. In this part of the why of Reverse Logistics, we will first reflect at a high level over the receiver perspective, i.e. the driving forces for companies and other organizations to become active in accepting returns or in recovery. Later we will consider the returning party. We categorize the driving forces under three headings, viz.

- Economics (direct and indirect);
- Legislation;
- Extended Responsibility;

Economics as a driving force relates to all recovery actions where the company has direct or indirect economic benefits. The previous regards profit from recovery actions, e.g. because of abating costs, dwindling on the use of materials, or obtaining valuable spare parts. Even with no clear or immediate expected profit, an organisation can get (more) involved with Reverse Logistics because of marketing, competition and/or strategy drivers. Companies may get involved with recovery as a strategic step to get prepared for future legislation. On the other hand, a company may envisage certain conditions in the long-run, e.g. impending legislation. In face of competition, a company may recovery to prevent other companies from getting their technology, or from preventing them to enter the market. A company may recovery to get a good (environmental) image with the customer or getting a better relation with the customer. An example is a tyre producing company who also offers customers rethreading options in order to reduce customer's costs. Having a green line of products can be as well part of a customer relationship strategy, especially due to the increase of environmental consciousness by society as a whole.

Legislation refers here to any jurisdiction indicating that a company should recover its products or accept them back, e.g. packaging recycling quotas in Europe (see EUROPA, online) and home shopping right to return in some countries as UK (see Office for Fair Trading, online).

Extended responsibility concerns a set of values or principles that in this case impel a company or an organisation to become responsibly engaged with reverse logistics. For instance, the concern of Paul Farrow, the founder of Walden Paddlers, Inc., with "the velocity at which consumer products travel through the market to the landfill", pushed him to an innovative project of a 100-percent-recyclable kayak (see, Farrow et al., 2000).

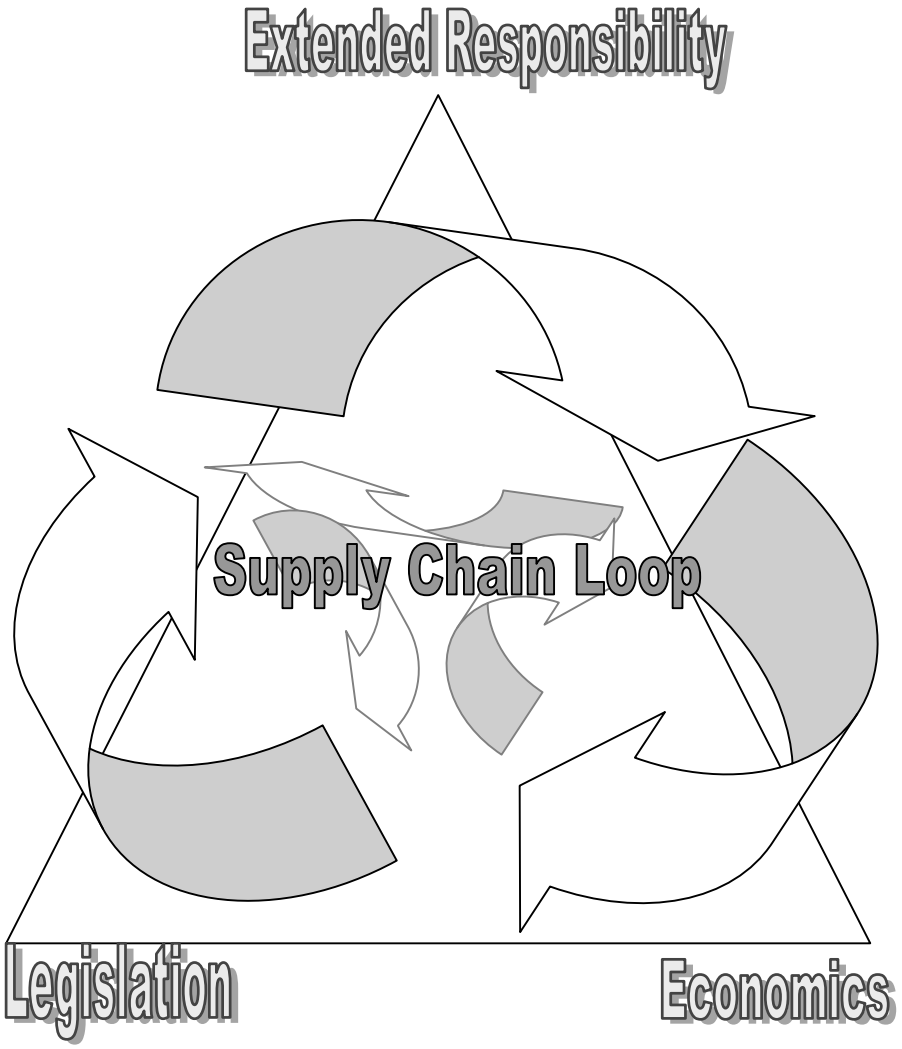


Figure 1. Driving triangle for Reverse Logistics in the Supply Chain Loop.

One should note that Reverse Logistics is often done for a mix of reasons: what may seem ethical in the short run is hopefully economical in the long run. Figure 1 depicts the driving triangle for Reverse Logistics.

Why (2): Return reasons

In the previous section we considered the driving forces for reverse logistics from a receiver perspective. In this second part of the why of reverse logistics, we reflect at a lower level through the returner/initiator perspective. Roughly speaking products are returned or discarded because they either do not function properly or because they or their function are no longer needed. We will elaborate these reasons and categorize them under three main headings according to the supply chain stage in which they occur. In this respect we take a somewhat more comprehensive view than most other authors. This is justified because all these streams have Reverse Logistics aspects. The return reasons are listed according the usual supply chain hierarchy, starting with manufacturing, next the wholesaler / retailers and finally the customers/consumers which in principle are going to use the products. Accordingly we differentiate manufacturing returns, distribution returns and customer/user returns. One should keep in mind however that manufacturers are as well part of the supply chain. With ‘manufacturing returns’ we consider returns during the production process, while returns involving the manufacturer as a chain actor are included in distribution

returns. Yet, a precise demarcation between these stages is not straightforward as final production may be done in the distribution chain.

Manufacturing returns

We define manufacturing returns as all those cases where components or products have to be recovered in the production phase. This occurs for a variety of reasons. Raw materials may be left over, intermediate or final products may fail quality checks and have to be reworked and products may be left over during production. The first and the last represent the product not-needed category, the latter the "faulty" category. In sum, manufacturing returns include:

- raw material surplus;
- quality-control returns;
- production leftovers;

Distribution Returns

Distribution returns refers to all those returns that are initiated by a supply chain actor during distribution after the product has been made (including the manufacturer). It refers to product recalls, commercial returns, stock adjustments and functional returns. Product recalls are products recollected because of safety or health problems with the products, and the manufacturer or a supplier usually initiates them. Commercial returns are all those returns where a buyer has a contractual option to return products to the seller. This can refer to wrong/damaged deliveries, or to unsold products that retailers or distributors return to e.g. the wholesaler or manufacturer. The latter include outdated products, i.e.those products whose shelf life has been too long (e.g. pharmaceuticals and food) and may no longer be sold. Stock adjustments go on when an actor in the chain re-distributes stocks, for instance among warehouses or shops. Finally, functional returns[2] concern all the products that its inherent function makes them going back and forward in the chain. An obvious example is the one of distribution carriers as pallets: their function is to carry other products and they can serve this purpose several times. Summarizing, distribution returns comprehend:

- product recalls;
- commercial returns (e.g. unsold products, wrong/damaged deliveries);
- stock adjustments;
- functional returns;

Customer/User Returns

The third group consists of customer returns, those returns initiated by a customer or user and/or as a result of consumption/use, in the large extent). Again there is a variety of reasons to return the products, viz.

- reimbursement guarantees;

[2] We introduce the term "functional returns" while many authors refer simply to "distribution items" or "distribution carriers" as a type of return. In the why-what context of the framework, "functional returns" befalls in the why while "distribution items" is then a category of the what (see next section).

- warranty returns;
- service returns (repairs and spare-parts);
- end-of-use;
- end-of-life;

The reasons have been listed more or less according to the lifecycle of a product. Reimbursement guarantees give customers the opportunity to change their minds about purchasing (commonly shortly after having received/acquired the product) when their needs or expectations are not met. The list of motives is long, e.g. with respect to clothes dissatisfaction may be due to size, colour, fabric's properties and so forth. Independent of the motive, when a customer returns a new product benefiting from a money-back-guarantee or an equivalent, we are in the presence of reimbursement guarantees returns. The next two reasons refer to an incorrect, functioning of the product (in a broad sense) during use. We like to remark that the word "use" should be interpreted broadly, e.g. an untouched spare part has served a function (potential back-up) while being there.

Initially, customers benefiting from a warranty can return products that do not (seem to) meet the promised quality standards. Sometimes these returns can be repaired and a customer gets a new product or his / her money back upon which the returned product needs recovery. After the warranty period has expired, customers can still benefit from maintenance or repair services, but they have no longer a right to get a substitute product. Products can be repaired at customer's site or sent back for repair. In the former case, returns do occur in the form of spare-parts since in advance it is hard to know precisely which components are going to be needed for the repair.

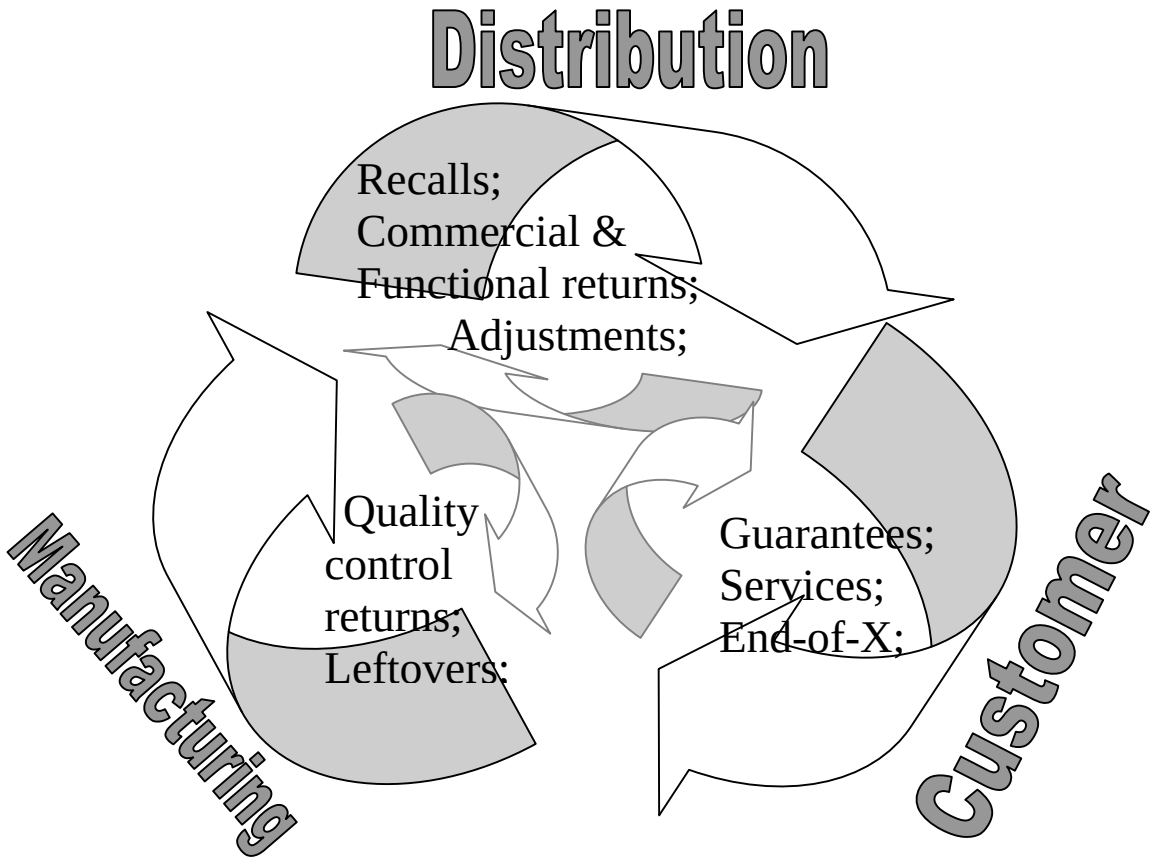


Figure 2. Return reasons for Reverse Logistics in the Supply Chain Loop.

End-of-use returns refer to those situations where the user has a return opportunity at a certain life stage of the product. This refers to leasing cases and returnable containers like bottles, or returns to second-hand markets as the one of *bibliofind*, a division of amazon.com for used books. Although end-of-use products are not really new, they are often in a good or reasonable state.

Finally, end-of-life returns refer to those returns where the products are at the end of their economic or physical life. They are either returned to the OEM because of legal product-take-back obligations or "returned" to another company for value-added recovery. Customers can be more or less active concerning the returns, as illustrated respectively by returning bottles to the supermarket, by sending back toner cartridges via mail (Bartel, 1995), or by having refrigerators collected at home (Nagel and Meyer, 1999). Deposit fees and charity's contributions are some of the incentives used by companies to stimulate (their own or other) customers to bring/send back the goods they would like to recover (see De Brito et al, 2002). From a broad perspective, a customer might not even be involved with the "return" of products ("return" in the sense of climbing the supply chain hierarchy - with respect to customer). This occurs for instance in the case of recycling of construction waste (see Barros et al., 2002). However, those are cases in the boundary between Reverse Logistics and Waste Management.

Figure 2 summarizes the reasons for Reverse Logistics in three stages of a Supply Chain Loop: manufacturing, distribution and customer/user.

What: Types and characteristics of returned products

A second viewpoint on Reverse Logistics can be obtained by considering *what* is actually being discarded or returned. In this respect it is not the product itself that is important but its characteristics.

Three characteristics seem to be relevant, viz. product composition, product use pattern and product deterioration since they affect recovery. Below we will discuss them in detail.

The *product composition* comes forward in four aspects, viz.

- ease of disassembly (is it easy to remove some parts or not, like removing chips from old computers which may be re-used).
- homogeneity of constituting elements (consists a product out of one component or multiple: this plays a role in recycling where one wants to obtain homogeneous components in order to use them as feedstock for new materials. Plastics are notoriously difficult to separate, which limits recycling)
- presence of hazardous materials (batteries with toxic materials in monitors or PCs need to be removed before these products can be recycled)
- ease of transportation: does the product need specific transport or not. Collection of old and distribution of new items can sometimes be combined (e.g. re-usable bottles) which lowers transportation costs, but may also give

problems in case of dirt coming from the collected items (e.g. refrigerators). . Empty bottles are expensive to transport, so local solutions are preferred.

These aspects normally affect the economics of reverse logistics activities. They determine whether it will be profitable to disassemble and do parts recovery or to destroy the product structure followed by material recycling. All these characteristics are product intrinsic and they are determined during the product design. That is also why it is that important to take product recovery into account while designing a product (design for disassembly).

The *product use pattern* affects the collection of the items and is related to the amount of deterioration that the product has experienced. It can be split up into two aspects, viz.

- location of use: the more use locations the more difficult collection is. Many food and drink packages are thrown away at the spot of use and expensive collection needs to be done. Another example is diaper collection by the firm *Knowaste* in the Netherlands: they concentrate on bulk users and not on individual households as collection would otherwise be too expensive. So the location of use determines the cost of collection.
- intensity and duration of use: It makes a difference if the use is constant for a long time or short / occasional, as occurs with hiring. For instance, distribution items, like containers, bottles, pallets and crates, are used by their receiver only for a short time during which they do not really deteriorate. Hence they can often be re-used, but they first need collection and a check before re-use.

Finally there are the *deterioration* characteristics, which determine whether there is enough functionality left to make a further use of the product, either as a whole or as parts. This strongly effects the recovery option. The following aspects play a role.

- intrinsic deterioration: how fast does the product age during use. If a product is consumed totally during use, such as gasoline, or if it ages fast, like a battery, there are limited reuse options and recycling may be the only option.
- reparability: can a product be easily repaired or upgraded to a better condition? Is an easy fault diagnosis possible? Rotable items, like rechargeable batteries can be easily restored to an as good as new condition. This aspect plays very much a role for service and warranty returns. As repairs tend to be a manually intensive, they tend to become more and more expensive and quite often one resorts to recycling.
- homogeneity of deterioration: do all parts age equally, or not? The preference is the former, but that is not always possible. In the latter case the product may be a candidate for remanufacturing or parts recovery.
- economic deterioration (due to new products arriving on the market): products may become obsolete because their functionality becomes outdated, like computers. This offers a potential for re-use in a secondary market or for parts recovery.

Based on these characteristics we will make a subdivision of products being returned, while we also separate intermediate streams, either from manufacturing or recovery. For products there are several categorizations from the UN for trade, etc.

Unfortunately, there are not always useful for reverse logistics. That is why we will distinguish the following product types

- food
- civil objects (buildings, dikes, bridges, roads, etc)
- consumer goods (white and brown goods, furniture, etc)
- industrial and professional equipment
- transport equipment (vehicles, planes, ships, etc)
- packaging and distribution items
- mineral oils, oil products and chemicals
- pharmaceuticals
- military equipment

All these products have different characteristics and for all there recovery takes place, although each time differently and with different terminology and processes. Below we will motivate each category shortly.

- food which is left over in the food chain is often reprocessed and used as animal feedstock (a kind of recycling). As there have been many scandals concerning contaminated ingredients, quality issues and tracking and tracing through the chain have become very important.
- civil objects, like buildings, bridges, dikes and roads are often renovated during their long useful life, which can be seen as a kind of remanufacturing or refurbishing. When they are really obsolete, they are demolished and their waste is crushed, separated and recycled. There has been some occasions of re-using of bridges, but civil objects are usually non transportable.
- consumer goods are today produced in millions with increasingly shorter product life cycles. This has raised many environmental concerns with the result that within Europe there has been much attention to recycling. Remanufacturing occurs occasionally, as consumers have a preference for new products. Although repairs have a long tradition, the increasing labor wages make them unattractive and often disposal takes place of failed products.
- industrial goods tend to be more expensive than consumer goods. Moreover, firms often take a more rational view than individual customers. Remanufacturing is therefore much more popular, especially in leasing cases such as aircraft engines, photocopiers and tires.
- transport equipment, a specific subcategory of industrial goods, has a long tradition of remanufacturing, parts recovery and recycling. For cars there are extensive recycling schemes in Europe and extensive remanufacturing takes place in the US. The standardization and multitude make recovery attractive. Quite often they are complex assemblies with a reasonable life time, with much metal, hence they have a high material value.
- mineral oils, oil products and chemicals (all fluids). They are either consumed during use (e.g. gasoline) or are processed in a complex way. This makes their remanufacturing difficult, but it is done if a large volume can be collected (e.g. gasoline vapor recovery) or if recovery is mandatory or environmentally important.
- pharmaceuticals are characterized by small amounts and stringent regulations. Most returns occur when they pass their shelf time.

- military equipment is a special case of industrial goods, where the processing has to occur in a controlled way. Specific cases are the destruction of nuclear weapons and other dangerous weaponry. During the life there is much remanufacturing and parts recovery. Recycling is applied only in a limited way.

Finally, the intermediate streams worth mentioning are metal scrap, paper pulp, wood pallets, etc. They are the result of recycling.

How: Reverse logistics actors and processes

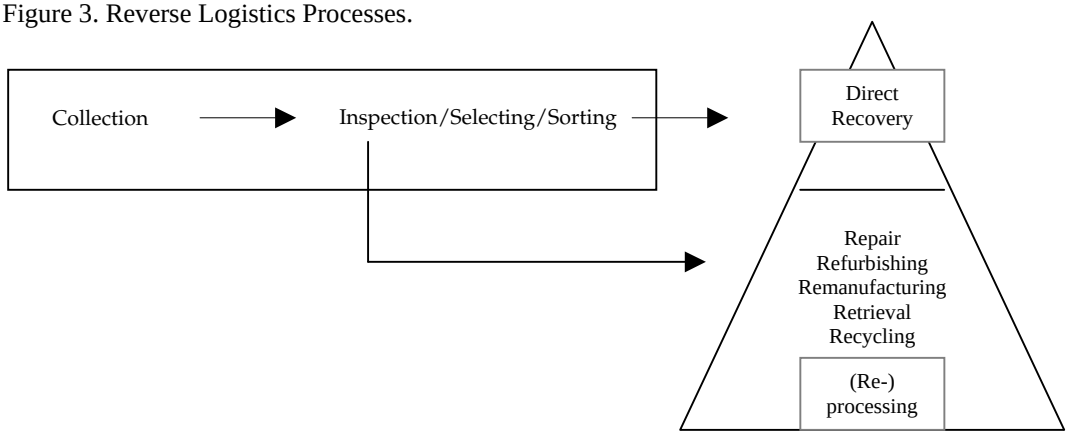
The third and last viewpoint is to see how Reverse Logistics works in practice: the actors and the processes involved (how is value recovered from products). Actors can be differentiated into returners, receivers and collectors / processors. Any party can be a returner, including customers. Receivers can be found in the whole supply chain, hence suppliers, manufacturers, wholesalers, retailers. Next there is a group of actors involved in reverse logistic activities, such as collection and processing. They are independent intermediaries, specific recovery companies (e.g. jobbers), reverse logistic service providers, municipalities taking care of waste collection, public-private foundations created to take care of recovery. Each actor has different objectives, e.g. a manufacturer may do recycling in order to prevent jobbers reselling his products at a lower price. The various parties may compete with each other. In general we see different structures for the different recovery options: the company doing also the sales of new products normally does re-use, unless it is a re-use in a secondary market. Remanufacturing can be done by the OEMs (photocopiers) or by independent companies (e.g. motor refurbishing) and recycling is quite often done in a public-private partnership with a foundation doing the organisation. Public entities are usually involved with a first stage of collection, in combination with waste collection. It will be clear that for private companies economics and legal are the main drivers, while for public entities it is mainly ethics and legal.

Several types of recovery can be distinguished; we separate between product recovery, component recovery, material recovery and energy recovery. In product recovery, products may be re-used in the original market (like containers) or in a secondary market. In case of component recovery, products are dismantled and their modules or parts can either be used in the manufacturing of the same products (remanufacturing) or of different products. Another option is that the product, then merely being a large installation, building or other civil object gets a refurbishment after which it is again in a better state. In case of recycling products are being grinded and their materials are sorted out and treated in order to get the desired quality after which the materials are being reused, like paper pulp and glass. Finally in energy recovery products are burned and the released energy is captured, being re-use, remanufacturing, recycling or disposal (incineration or land filling).

There are four main reverse logistic processes. First there is collection, next there is the combined inspection / selection /sorting process, thirdly there is re-processing or direct recovery and finally there is redistribution (see Figure 3). Collection refers to bringing the products from the customer to a point of recovery. At this point the products are inspected, i.e. their quality is assessed and a decision is made on the type of recovery. Direct recovery embraces re-use, re-sale and re-distribution. Re-

processing includes the following options: repair, refurbishing, remanufacturing, retrieval[3], recycling and incineration. Finally, redistribution is the process of bringig the recovered goods to new users. For complete definitions, see Thierry et al. (1995).

Figure 3. Reverse Logistics Processes.



In the inspection / selection and sorting phase products are being sorted according to the planned recovery option and within each option, products are sorted according to their quality state and recovery route. As a last phase in the recovery products undergo some kind of processing. This can consist of dismantling and/or grinding, again a sorting, a testing and possibly a (re)manufacturing. In dismantling the product is split up into parts or components, which may undergo a separate recovery. In grinding the product structure is destroyed and its materials may be recycled after sorting. These actions may be combined, e.g. one may first remove batteries from a monitor and then grind it.

The condition of returned products may be derived from the return reason. They determine very much whether the product can be re-used or remanufactured. If that is not the case then only recycling or disposal are left over as recovery options. For example, supply chain returns normally refers to products in good condition (unless damaged in transport and or if they are recalls). They can often be re-used, but not always be sold as new. Yet they may be sold at a discount or at a secondary market. Warranty returns may often be repaired, but sometimes the needed effort for testing and repair does not pay (economically) off. End-of-use returns are often deteriorated, but they may contain valuable components that can be re-used. This is e.g. the case with photocopiers.

Why, what & how: Interrelations

In the previous sections we gave context to Reverse Logistics by presenting brief typologies for the return reasons and driving forces (why), for the type of products (what) and for the recovery processes (how). These basic characteristics are interrelated (see Figure 4).

For instance if the returns flow is of yogurts that have passed the due date, direct re-distribution is out of question. The same is the case if the return reason is a recall, as recently happened with a digital camera model of Kodak suspected of giving electric

[3] Thierry et al. (1995) use the term cannibalisation, for the "selective retrieval of parts." In the US demanufacturing is often used.

shocks. It is out of the question to list all possible interrelations between return reasons, drivers, products and processes. What we want to stress however is that it is important to be conscious of these interrelations, as decisions are taken. Above, we have mentioned some obvious examples. Yet, awareness of further complex interrelations should be at any decision process.

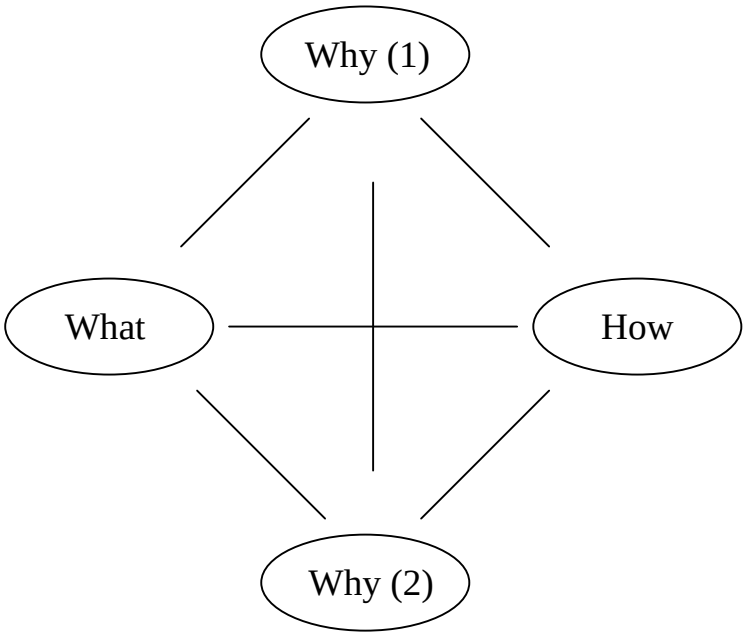
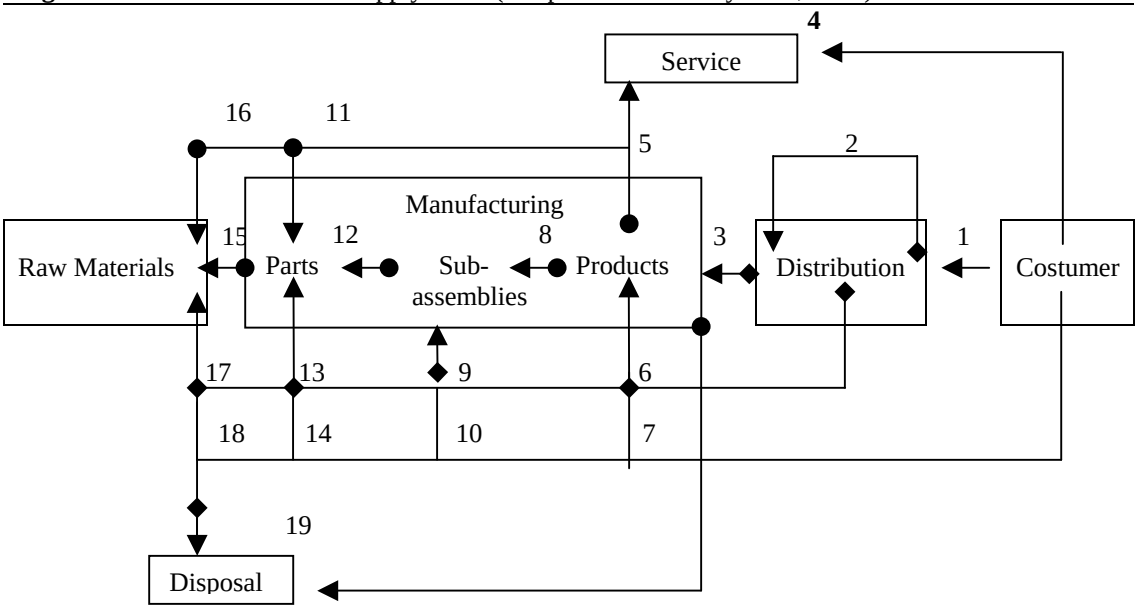
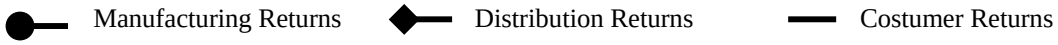


Figure 4. Interrelated Reverse Logistics characteristics.

In particular, Figure 5 represents a variety of reverse flows occurring at different stages of the supply chain. Each reverse flow has associated the return reason (why) as well as the type of recovery (how) that it is likely to occur.

Figure 5. Reverse flows in the supply chain (Adapted from Thierry et al., 1995)

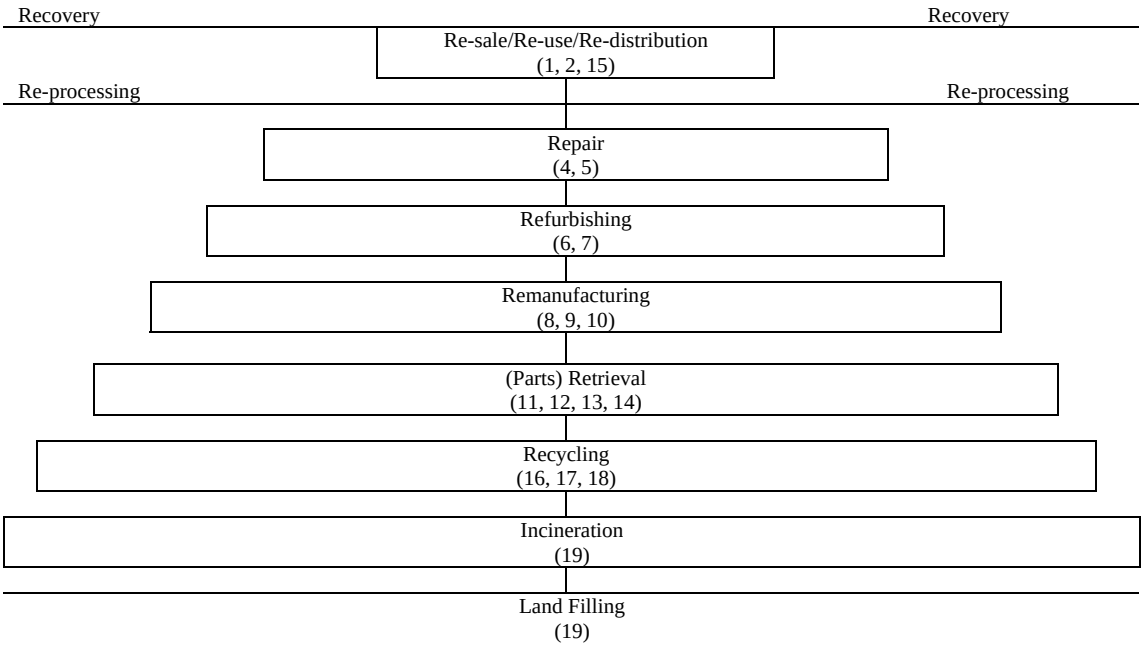




1. Reimbursement, End-of-use (Re-sale, Re-use)
2. Commercial & Stock adjustments (Re-distribution)
3. Recalls (Re-processing)
4. Warranty, Service (Repair)
5. Faulty Products (Repair)
6. Commercial returns, Recalls (Refurbishing)
7. End-of-Use, Warranty (Re-furbishing)
8. Faulty products (Remanufacturing)
9. Commercial returns, Recalls (Remanufacturing)
10. End-of-Use, End-of-Life (Re-manufacturing)
11. Faulty products (Retrieval)
12. Idem
13. Commercial Returns, Recalls (Retrieval)
14. End-of-life, End-of-Use (Retrieval)
15. Raw materials surplus (Re-use, Re-sale)
16. Faulty Products, Production Leftovers (Recycling)
17. Commercial Returns, Recalls (Recycling)
18. End-of-Life (Re-cycling)
19. All Reverse Flow Types (Incineration, Landfilling))

Figure 6 depicts the recovery option pyramid. Recovery options at the top of the pyramid are of high value, while options close to the bottom recover less value from the products. One can notice that for all the three stages (manufacturing, distribution and customer) there are low value (as landfilling) and high value (as Re-distribution) recovery options. By again paying attention to Figure 4, one observes that short "trips" with respect to the supply chain hierarchy are in favour of high recovery ratios.

Figure 6. Recovery option pyramid in the supply chain (see numbers at Figure 5).



As informally addressed in the previous contextual sections some of the decision process involves collection, the planning and scheduling of recovery operations, inventory control and relations in the supply chain. Next, we formally present a

decision framework for Reverse Logistics, approaching it from three levels: strategic, tactic and operational.

5. A decision framework for Reverse Logistics

We look upon the decisions regarding Reverse Logistics at three phases: strategic, tactic and operational. To build up this hierarchy we used as input the taxonomy of Ganeshan et al. (1999) and the review of Schmidt et al. (2000). Besides this, we take into account the traditional functions of a firm (procurement, marketing and so on). To be involved with Reverse Logistics, a firm does not necessarily have to follow the decision hierarchy step by step. In particular, in presence of legislation a firm may not have room to decide whether to recover or not.

Table I A decision Framework for Reverse Logistics

Strategic decision level
o RECOVERY (OPTION) STRATEGY o PRODUCT DESIGN o NETWORK CAPACITY & DESIGN o STRATEGIC TOOLS
Tactic decision level
o PROCUREMENT & INTEGRATED MANAGEMENT o (REVERSE) DISTRIBUTION o CO-ORDINATION o PRODUCTION PLANNING o INVENTORY MANAGEMENT o MARKETING o INFORMATION & TECHNOLOGY
Operational decision level
o PRODUCTION SCHEDULING & CONTROL o INFORMATION MANAGEMENT

The reader is certainly familiar with a strategic-tactic-operational perspective on decision-making. At the strategic level, befall decisions that are long-lasting also because they are hard to change. The previous considered issues during the why/what/how analysis of Reverse Logistics confine every decision to be taken. To start with, whether or not to do recovery and if so which type of recovery. The driving forces work as a sort of supra-objectives. The return reason, together with the inherent product characteristics give an idea whether high value recovery is, or not, possible. In this way, a spectrum of the return option pyramid can be selected. The recovery option can be taken into account during the design of the product, by including design for recovery. In fact as some decisions become fixed, other decisions become further constrained given that one would like to maintain efficiency. Therefore, every decision has to bear the impact on other decisions. Network design can actually be network re-design as recovery can be being put on top of an already existent supply

network. The issues here are where to locate warehouses, re-distribution plants and so on and at the same time allowing for enough future capacity. One can also think about all kind of tools to support strategic decisions.

At the tactical level, and internally one has to integrate product returns with the overall organization. In particular, the transport, handling and the warehousing of returns have to be dealt with. One of the issues is the procurement taking into account product returns. For this, one has to decide on which forecasting techniques to employ. In addition, one has to care for the immediate relations in the chain. To start with firms may consider to outsource (partially) return operations. Accordingly, coordinating mechanisms have to be set. Furthermore, there are typical production planning and inventory management decisions but now taking into account product returns and recovery. In particular, the value of recoverable/recovered products has to be determined. A way to take to the market recovered products has also to be found. Supportive IT systems has also to be thoroughly though about. For instance, Which IT systems are to be in place to handle returns? Which information is to be kept and for how long? Will it be in place return handling dedicated software?

At the operational level, we find production scheduling & control related decisions as the disassembly and reassembly operations. More detailed schemes to monitor, share and control information have to take also place at this level

6. Final Remarks

In this article we have given

- A comparison of Reverse Logistics definitions, and an historic perspective of the evolution of the term. In addition we introduced the RevLog definition (see online bibliography).
- An understanding framework of Reverse Logistics (why, what and how)
- Within the understanding framework, we put in context the forces driving companies to be engaged with Reverse Logistics, we provide a typology of return reasons, and further classifications on types of products, processes and actors.
- Interrelations between the basic structure (why, what and how) helping to view the complexity of Reverse Logistics systems;
- A decision framework for Reverse Logistics based on a long, medium and short term perspective, i.e. strategic-tactic-operational decisions.

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EUROPA, the European Union On-Line.
http://europa.eu.int/index_en.htm

OFFICE FOR FAIR TRADING
http://www.oft.gov.uk/

RevLog, the European Working group on Reverse Logistics (1998-),
http://www.fbk.eur.nl/OZ/REVLOG/.