VAASAN YLIOPISTO

ISABEL FERNÁNDEZ

Reverse Logistics Implementation in Manufacturing Companies

ACTA WASAENSIA

No. 127

Industrial Management 8

UNIVERSITAS WASAENSIS 2004

Reviewers

Docent Everth Larsson

Lund University
Department of Industrial
Management and Logistics
Box 118
221 00 Lund (Sweden)

Dr. Olga W. Lemoine

Institut for Transportstudier
Hærvejen 11C
Postboks 6
DK-6330 Padborg (Denmark)

FOREWORD

The development of this thesis, as any other project in life, is a path were some extraordinary people is encountered, at times even unexpectedly, which makes the experience unique and difficult to fade away. Therefore and although in the cover only one name is expected, many are the names of people who, one way or another nurtured it, and to whom I am pleased to devote my most sincere and deep gratefulness.

Specific recognition are given to my two supervisors, Josu Takala and Tauno Kekale for, first giving me the opportunity of grasping a turnpoint when it was needed; secondly, for providing a supportive atmosphere that allowed the completion of this thesis. Their quality support and wise guidance throughout the whole process, steering but without imposing, suggesting but keeping freedom intact, has been invaluable. Gratefulness exceeds thesis-related boundaries as my learning has transcended the mere topic of this work. Their imprint will outlast both distance and time.

The author would like also to express her special appreciation to the examiners for their constructive comments and enlightening remarks. Their help and kindness have been extremely meaningful for me.

Without the contributions of a number of, sometimes anonymous, individuals in companies this undertaking would not either have been possible. In spite of their always busy agendas, they provided with their valuable time and assistance and shared their expertise, all of which was crucial mainly for the empirical part of this work. The documentation and hints are also fully appreciated.

The author is greatly indebted to a number of her colleagues for insightful comments in the drafting of this work. To all those mainly friends (but not also) who, with their loyal warmth, looked after my moral side and supported me even from the long distance, I am indeed grateful.

Finally, to my family who insufflate permanent courage and love and without whom any effort would not have made sense.

CONTENTS

page

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMES

AHP	.....	Analytical Hierarchy Process
CR	.....	Consistency Ratio
EDI	.....	Electronic Data Interchange
ICT	.....	Information and Communication Technologies
LCA	.....	Life Cycle Analysis
MRP	.....	Material Requirement Planning
OEM	.....	Original Equipment Manufacturer
PRM	.....	Product Recovery Management
WEEE	.....	Waste Electric and Electronic Equipment

ABSTRACT

Fernández, Isabel (2003). Reverse logistics implementation in manufacturing companies. *Acta Wasaensia* No. 127, 225 p.

European Directives oblige to recover a lot of products – durable goods, packaging, car components, electric and electronic devices and so on. This fact along with some other pressures – customers concerns, economical reasons – will imply in the very next future an important modification of the operational processes in companies as well as the opportunity for a new market (transport providers, warehousing, among others). The outcome seems to be that the reverse logistics will strongly impact the companies and most likely, will become one of the most growing businesses in the future coming.

Reverse logistics has been considered as the reverse version of the traditional logistics. This view of perhaps the most recent sub-field within the logistics reveals to be quite naïve. Decisions about the implementation of efficient reverse logistics process pose companies a series of difficult challenges. Although some corporations have already succeeded in adopting the required practices, they are still scant in number even when talking in worldwide terms. Reasons behind this do not seem to be so apparent.

The aim of this thesis has been twofold. On the one hand, to contribute to the theoretical framework as, due to the short life of this emerging discipline, there is not yet a theory nor extended neither unanimously accepted, as it will be demonstrated in the section devoted to the concept review. On the other hand, such contribution was requested to be nurtured from real settings. This line of work was what mainly defined the methodology to be used along the most part of the investigation, being this qualitative research. More specifically, focus group was firstly used with the objective of gathering information from experts on the subject. The main problems that jeopardize the good end of reverse logistics procedures and about which a deeper academia attention could be needed were enquired. Results helped to better delineate the initial research question. In a second stage, we choose the case study methodology so that several companies were deeply analysed. When little is known about a specific topic, this methodology has proved to be one of the most appropriate to get deep insight. The main findings obtained were given the form of propositions to be generalized in future research. Finally, we resorted to AHP (analytical hierarchy process) approach to extrapolate the previous results with a more ample sample.

Isabel Fernández, Faculty of Technology, Department of Electrical Engineering and Industrial Management, University of Vaasa, P.O. Box 700, FIN-65101 Vaasa, Finland. Email contact address: ifq@uwasa.fi ; bel@etsiig.uniovi.es

Keywords: Reverse logistics, challenges, qualitative research, analytical hierarchy process

1. INTRODUCTION

1.1. WHERE IN SCIENCE IS REVERSE LOGISTICS

Science (from scientia, Latin for "knowledge") has come to mean a body of knowledge, or a method of study devoted to developing this body of knowledge. Fields of study are often distinguished in terms of hard sciences and soft sciences (Economics, Linguistics, Etymology, Psychology, Sociology). Hard sciences are considered those, which rely solely on the scientific method, this method being distinguished by its use of controlled experiments and the requirement that results be reproducible.

Table 1. Classification of sciences (adapted from Uusi-Rauva, Haverila & Kouri 1994).

FORMAL SCIENCES	**EMPIRICAL SCIENCES**		
	CULTURAL SCIENCES/ HUMANITIES	**SOCIAL SCIENCES** (BEHAVIOURAL SCIENCES)	**NATURAL SCIENCES**
NO EMPIRICAL	*RULES SYNTAXES*	*DECISION-MAKING*	*NATURAL PHENOMENA*
MATHEMATICS LOGIC	LINGUISTICS LAW HISTORY	ECONOMICS SOCIOLOGY PSYCHOLOGY POLITICS	CHEMISTRY PHYSICS BIOLOGY EARTH SCIENCES

Another classification separates formal sciences from empirical sciences (see table 1). Formal sciences are deductive. They could be characterized by the following features: they are derived abstractly (mostly without experiments), using law thought; they alone do not tell us anything about the practical reality we live in and they usually offer symbolic systems to denote reality. Empirical sciences however are inductive; they do investigate

reality and reliable knowledge is gained through practical (sensory) experience and experiments.

Within social sciences category we found Economics, which focuses on society's allocation of scarce resources to meet desires and wants. Its main premise is therefore that resources are in limited supply and that it is necessary to choose between competing alternatives. Economics may be broken down in micro and macroeconomics. It is within micro-economics that we find Industrial Management.

Industrial Management is the field of Economics that studies the behaviour of firms; also referred to in some texts as Operations Management, it is more specifically concerned with the systems, processes, and activities involved in the production of the goods and/or services of an organization. Operations Management focuses not only in manufacturing but also in service activities including facilities, systems and operations, management of technology, quality assurance, materials management, logistics and supply chain management.

Therefore, Logistics is an element within the more ample discipline of Industrial Management. The origins of the word "logistics" lie many centuries in the past; in fact we may go back as far as the Greek culture to find the term "logos" (intellect, arithmetic) as the oldest relative of our nowadays Logistics. However it is in the XVIII century when its use adopted a closer meaning to the one it holds today; at that time, in France, the position of the "maréchal de logis" was created within the Napoleonic army for a person responsible for providing sufficient supplies for the troops. Over time, this area of responsibility has shifted from military to civil context and has become more comprehensive, adding to the mere supply function other functions such as the planning of the transportation or, lately, the reverse logistics.

The history of Industrial Management is much more recent. Prior to 1750 products were manufactured quite differently than they are today. Production before the advent of the

Industrial Revolution could be characterised by direct contact between producers and consumers, little mechanization, bespoke production, custom-made and personalised products. It is in the late 1800's and early 1900's when the first snaps of a theory of management appear as it is generally accepted that Taylor's theory supposed the start of Operations Management. This starting point led to other posterior theories, methods and studies of management, such as the Hawthorne studies[1], Just-in-time[2], Decision theory[3], or Material requirements planning[4], among others (see Annex 1 of this thesis).

During the evolving process of Industrial Management, science has been tracking down the logistics techniques and applied them to civil companies. Transportation management and materials management by companies were economic topics back in the 50's, although research was still then normally restricted to just some of the aspects of today's comprehensive understanding of logistics. Only in the last four decades has the modern term "logistics" been used to describe business management issues: the right object, at the right time, at the right location, in the right quality, in the right combination, at the right cost –including the related data-.

In the last two decades we have seen a momentous social and economic change, which may suppose the next major step in the evolution of logistics, this step now beginning to emerge. This change takes place, initially, as a consequence of the increasing consciousness about sustainable development and environmental issues, from both population and public institutions. Some of the regulations passed are:

---

[1] (1930) A series of experiments conducted by researchers from the Harvard Business School at Western Electric Company's Hawthorne unit which illustrated the importance of human aspects in determining output and productivity.

[2] (1950s) An integrated set of activities designed to achieve high-volume production using minimal inventories of raw materials, work in process, and finished goods" (Chase, Aquilano & Jacobs 1998). In simpler laymen terms it means, "producing the required items, at the right quality, and in the exact quantities, precisely as they are needed.

[3] (1960s) Body of knowledge and related analytical techniques of different degrees of formality designed to help a decision maker choose among a set of alternatives in light of their possible consequences.

[4] (1970s) Logically related procedures, decision rules and records designed to translate a master production schedule into time-phased net requirements, and the planned coverage of such requirements, for each component inventory item needed to implement this schedule.

- the Directive 2000/53/EC on end-of-life vehicles (EOLV), which establishes minimum targets with respect to the quantitative re-use, recycling and recovery rates for all EOLV to be implemented no later than 01/01/06;
- the Directive 94/62/EC, which contains provisions on the prevention of packaging waste, on the re-use of packaging and on the recovery and recycling of packaging waste: 80% of all packaging must be collected; of that, 90% of glass, tin & aluminium and 80% of other packaging must be separated and recycled (Cairncross 1992).
- Directives 2002/95/EC on the restriction of the use of certain hazardous substances (lead, mercury, cadmium, and hexavalent chromium among others) in new electrical and electronic equipment put on the market from 1 July 2006, and 2002/96/EC on waste electrical and electronic equipment (WEEE).

In most of these legislations, manufacturers and importers are obliged to take back their products (even at no charge) and they are responsible for achieving the high levels of recycling, recovery and reuse. Therefore, although the involvement in reverse logistics practices may still be considered today as an additional feature in corporations' competitiveness, it is expected shortly to become, an essential and imperative prerequisite for the compliance with legislation and the success of firms in the market. Logistics strategies in companies need to be adapted to the new conditions under which their businesses have to operate and tailored according to the new characteristics. The challenges for companies are to plan strategies specifically built upon logistics as a means of achieving competitive advantage (Emerson & Grimm 1996; Sterling & Lambert 1989). As a consequence of it, a new field of logistics has been developed: reverse logistics. Although some firms may react reluctantly to the pressure the change inflicts on them, some have already discovered the economical potential of an efficient management of the reverse logistics issue in their strategy.

In spite of the emerging nature of this discipline, the following numbers may give an idea of the importance and the benefits from planning, implementing and controlling reverse logistics activities:

- In the study carried out by Rogers & Tibben-Lembke (1999:5), reverse logistics costs of the analysed companies represented approximately four percent of their total logistics costs, which translated to the total U.S. GDP represented a half percent (Rogers & Tibben-Lembke 1999).
- Within specific sectors (such as magazine publishing), returns percentages may reach 50% of the total sales (Rogers & Tibben-Lembke 1999:7; Meyer 1999), although a significant variation in return rates occurs by industry.
- Efficient management of the reverse process can cut as much as 10% from companies' total annual logistics costs (Minahan 1998)
- Companies that sold merchandise on line were predicted to take back $11 billion in returns in 2002 (Richardson 2001).
- Companies involved in recovery activities may attain savings between 40 and 60% of the completely new product production costs, while investing only 20% (Dowlatshahi 2000).
- The department of transportation in Pennsylvania saved more than $250,000 in only one district by using recapped tires; also, American Airlines saved over $100,000 by converting to 100% recycled paper (Biddle 1993).
- Estèe Lauder was able to evaluate 24% more returned products, redistribute 150% more of its returns, and save approximately $500,000 in annual labour costs after building its own reverse logistics systems (Caldwell 1999; Meyer 1999).
- AT&T also saved $30.000 from its reverse logistics program (Dowlatshahi 2000).

The purpose of the thesis is to identify and systematize current industrial practices and trends in this new scenario of the logistics field and therefore, contribute to the still scant literature devoted to this topic. By doing so, a better understanding will be provided with which decision makers in this functional area can more effectively decide. Given the far-reaching of reverse logistics scope, to determine a specific focus within it was needed.

1.2. RESEARCH APPROACH

Research approach refers to the strategy followed in order to produce new knowledge. Reverse logistics is a new discipline in which not much theory has already been developed; some works have contributed to its incipient development and their consideration is valuable for the expertise and knowledge poured on them. Nevertheless, incremental approaches and further models and theory development are largely possible. On the other hand, stemming again from the novelty of the discipline, the full universe of problems has not yet still covered; therefore new areas can be explored and materialized in new conceptual and/or mathematical contributions.

Based on that and according to the taxonomy proposed by Reisman (1988) of the strategies for theory development in management and social science research, we have chosen a combination of two of those for the development of this thesis:

a) The "Ripple strategy" which consists of developing current theories incrementally, and
b) The "Structuring Strategy", which uses observations in a previously unexplored field to build up new theory.

Therefore, the approach could be said to be basically of inductive nature in the sense that the logic laying behind the investigation starts from the information gathered from qualitative research methodologies to round it off afterwards with a more quantitative approach in an attempt to reach the external validity typically scant in the qualitative methods. Given the little existence of theories on reverse logistics, the deductive process part that could be assigned at the beginning of the process (reviewing literature and analyzing the material gathered in the light of previous theoretical work) is modest.

The research approach put forward in this section is not new and is supported by Glaser & Strauss (1999). In their "call for more theory" (p. 8) they make a "defense against doctrinaire approaches to verification" (p. 7). Verification is, according to these authors, driven by the influential logic-deductive theorizing style and was used to modify and

reformulate already existing theories but hardly to question them, and thus generating new theories from data, that is, theories grounded in data, "grounded theories" (p. 9–10).

It is possible to build theories by using different methods: plausible interpretation and/or genuine verification of a well-codified set of propositions. The work showed in this thesis does not aim to be decisive test of existing theories but to suggest questions suitable for further discussion and better understanding. The data collection process is coherent with the research approach chosen. The basic questions in theoretical sampling, such as what group does one turn to, or, for what theoretical purpose, were posed and responded to as will be explained in next sections. Companies were chosen following the criterion of their potential to help generate, to the fullest extent, as many properties as possible. This idea guided the selection of organizations with international scope and the option of repairing within their spectrum of recovery activities. "There is not definite, prescribed, preplanned set of groups as there are for verification" (p. 31–49).

The qualitative research methodologies chosen have been focus group and case studies, both suitable and recommended when little is known about a particular problem or topic:

- The focus group technique was first meant to generate research questions that could be submitted to further research by means of other research methods; secondly, the focus group was also utilized for screening the relative importance of the different issues that arise when implementing reverse logistics practices. The targeted participants were experts in logistics themes from different fields.
- Next step was to accomplish case studies. The case studies are one of the best tools for going deeply in the reverse logistics knowledge by approximating real settings; they provide the researcher with learning from companies' doing, by gathering, processing and analyzing information from the firms' "why" and "how" decisions.

1.3. THE RESEARCH QUESTION AND ITS DEVELOPMENT

Although the research definition of this thesis should not be in the Introduction chapter if the natural order of the research were followed (see Figure 1), it was decided to include it in order not to depart from the norm, as it is usual a clear definition of the research question to be put forward in this chapter.

The reason for previous remark is that an ongoing refining process of the problem definition took place during a good while of the research. This is not utterly unusual if we take into consideration that while exploring the field, the initial proposal can be found too broad, some of its aspects may have become irrelevant or some assumptions may fall apart and need to be revised (Andersen, Borum, Kristensen & Karnoe 1995).

1.3.1. THE RESEARCH QUESTION

In this thesis an attempt is made to contribute to existing reverse logistics theory by providing a deeper understanding on the surrounding circumstances under which certain reverse logistics decisions are made. An important assumption behind is that the whole universe of companies needed to be addressed in order to get a seamless theory is impossible to tackle with. On this basis the research question adopted the following formulation:

"What are the characteristics of the reverse logistics practices in durable and assembled goods manufacturing companies which include repair within their customer support service? What factors may affect on their reverse logistics practices? How their businesses are affected by this new discipline?"

1.3.2. THE DEVELOPMENT OF THE RESEARCH QUESTION

The first attempt of the research question resulted after a still modest literature review on the topic. This review was needed to possess a prior picture (or scheme) of the empirical world under study (the first step in the basic elements of empirical exploration proposed by Blumer (1969)[5]). The resulting question was a broad one due to the still little spread out knowledge on reverse logistics practices, as a consequence of which, every facet of reverse logistics was feasible for being further researched. A deeper literature review and the need of narrowing the scope of the future thesis work led next to focus on just one of the echelons within the supply chain: *manufacturing companies*.

The orientation of the work would be governed a that time by:

"What are the characteristics in the reverse logistics practices in manufacturing companies? What factors may affect on their reverse logistics implementation? How their businesses are affected by this new discipline?"

The relative importance of the reverse logistics and their orientation was found to vary from industry to industry. The review of literature disclosed how reverse logistics practices have been embraced by companies belonging more to certain sectors of activity than to others. Electronic industry (including computers) and automotive industry clearly stood out as pioneers. Therefore and at this time of the research, not all kind of manufacturing companies was suspected to fit in the study. Further restrictions were required to better delineate the research question.

The relative importance of the reverse logistics and their orientation was also found to vary from product to product. In low cost products or consumable products, recovering did not appear to be so important; thus, neither the linked reverse logistics. However, in the case of

[5] The remaining elements are asking the questions and their conversion into problems; determination of the data to be sought and the methods to be used in obtaining them; processing the gathered information; interpretation of the findings.

durable goods with a long life cycle or assembled products with parts subject to wear, costs of maintenance/repairing may be even more important than initial product acquisition costs; on the other hand, some modules, assemblies or parts still in good condition are more likely entitled to be reused so that, added value is recovered. The importance of the reverse logistics activities in the latter case should play likely a bigger role. This justifies the election of companies, which produce *durable goods and assembled products* within the research question, as these kinds of products seemed to fit more within the reverse flows.

By doing that, we also wanted to verify if the characteristics of the product could have influence on the major or minor implication in reverse logistics operations. This idea would translate into researching if characteristics of the product such as size, weight, length of life cycle, its technological complexity, etc. could constitute conditioning factors for the manufacturing company to decide on being involved in the reverse logistics systems needed for handling with the product returns.

Still the research question was not easy to tackle with. As a result a final feature was included: the study will concentrate on manufacturing companies, which offer *repairing* within their customer service pack (their customers could be end customers or not).

Why this repairing scenario? As it will be seen later in this thesis, the activity of repairing implies that the company has previously deployed a certain degree of reverse logistics processes (if not in-house then by means of third party logistics providers). On the other hand, the activity of repairing seems to have been carried out for almost as long as there has been trade. In fact, there are a great number of pieces of work in literature, devoted to analyse the problems arisen as a result of its management, most of them focused on service parts inventory management (Dekker, Kleijn & de Rooij 1998; Shibuya, Dohi & Osaki 1998; Hill, Omar & Smith 1999). However, the aim of this thesis is not the activity of repairing in itself. Given that the author does not share with other authors the idea of including activities such as repairing (or remanufacturing or recycling) within the scope of

reverse logistics, strictly speaking (see section of definitions) the object of the present thesis is to focus on the unavoidable and previous logistics activities, needed for the repairing activity to be carried out. In this sense, for instance, the categorization of service parts into repairable items (those, which are technically and economically repairable) and consumable item (those, which are not technically and/or economically repairable), although important from inventory management perspective, is irrelevant for the purposes of the thesis i.e. both may fall within the focus of interest from the reverse logistics standpoint.

Repair is considered, especially recently, an important feature within the after-sales service and within the competitiveness of a company. In a market characterized by fierce competition and nearly identical products due to standard components and technologies being used (Murthy & Djamaludin 2002), post-sale factors constitute important differentiate factors (Porter 1998; Lele & Karmarkar 1983; Pfohl & Ester 1999; Botter & Fortuin 2000) on which not only the product or service choice can be made but a customer may be retained. Therefore, an improvement in their supporting reverse logistics would make sense, because they would contribute to improve the competitive position of the company in the market. However, in many organizations, consideration or design of the support processes is still nowadays an after-thought. There does not seem to be yet a generalized, holistic product development perspective[6] in which both design of support processes along with the design of the product are simultaneously considered. This fact may depend on the lack of a good understanding of the importance of several key variables, such as the quality of service, the costs of service supplied, the potential of effective reverse systems, etc.

As already mentioned, the choice of the reverse logistics procedures for the repairing activity allowed for narrowing the analysis field. The focus on companies, which included the repair of their products among their activities, eliminated the interest in other companies also involved in reverse logistics but with other recovery goals. Therefore it has

[6] Some exceptions exist; see for instance, Hooks & Farry (2001: 176)

to be said that repairing activity was chosen, with the same likelihood with which any other materials or value recovery activity could have been chosen. Why then repairing and not remanufacturing, for instance? Given that this returns context is a relatively emergent one and, consequently, not yet sufficiently neither broadly implemented in firms, we have considered that repair, because of its longer history, would allow us to find a larger number of cases on which to carry out the analysis of the adopted reverse logistics practices. In spite of this apparent initial advantage regarding the possible population size among which to choose the firms to study, we did not find a great number of companies directly involved in the implementation of (in-house) reverse logistics processes. This initial finding was striking, as from literature it seemed as if more companies were including these reverse logistics systems in their strategies and day-to-day operations. It will be shown that, not even in this case (and against what literature seems to point out) many companies exist directly involved in the implementation of reverse logistics processes.

1.4. STRUCTURE OF THE THESIS

Chapter 2 has been denominated "Overview of reverse logistics". Its contents aim at first, providing insight into key aspects of this emerging discipline and offering, therefore, the theoretical framework in which the subsequent work has been developed. Specifically, Section 2.1 is devoted to review the reverse logistics concept from a broad set of articles, published mainly in the last decade. From these, the author detected the lack of a consensus on what constitutes reverse logistics, either on what the range of activities should be included within its scope or how to denominate each of its close-related options in a non-fuzzy way.

The clarification of the concept matters for several reasons. On the one hand, most of the environmental regulations usually mention some objectives to be reached in certain periods of time, in relation to some of the reverse logistics related activities. As not only consumers but also companies and municipalities are committed with these goals, it would

be desirable to have a clear idea of what is meant by each denomination and the implications that each one may have.

On the other hand, having a definite guideline of this conceptual framework would allow for some comparative studies about the different levels of implementation within the members of the chain or between different channels, being more accurate and reliable. On a literature review basis, the section concludes by providing a reasoned concept proposal for this new part of the Logistics that will be used in the rest of this thesis.

The remaining sections of this chapter 2 put forward some dimensions affecting the reverse logistics implementation and the unique characteristics of this new discipline.

Chapter 3 has been devoted to the empirical research developed to accomplish this thesis. This chapter consists of four parts. The first is intended to give some insight in the methodologies chosen and to justify why the qualitative research is a valid tool to be used in a discipline like Operations Management, a discipline which has been traditionally deemed as the natural realm for quantitative techniques. Three different methodologies were considered suitable for the study: the Focus Group, the Case Study and the Analytic Hierarchy Process (AHP). The selection of each of them grounds on the different objectives pursued.

- The focus group was used as the first methodology to explore areas of research interest within this relatively recent sub-field of reverse logistics. From a broad review of literature to date dealing with reverse logistics, several gaps where additional research according to the opinion of the author was possible were identified. Making the most of both these evident gaps and the opportunity provided by Focus Group technique in areas in which little is known, as is the Reverse logistic case, two meetings were organized.

As it will be shown in Section 3.2 the composition of the two focus groups was planned to be different: In one of them, academicians in general Logistics and from different European countries were invited. In the second one, characterization differs, as the participants were managers with strong reverse logistics responsibility within the local Finnish enterprises where they work.

Ideas from both groups were intended to be confronted, given the different nature of source from where they stemmed, and to serve as initial point of a larger effort in which deeper empirical analysis in several firms, running their business in different sectors, would next take place.

- The commandant Krulak (1997) stated that logistics, apart from being science, is an art. As such, it includes the creative application of scientific knowledge through judgement, experience and intuition to devise practical solutions. When circumstances change, good logisticians are expected to be flexible and ingenious in adapting to the new situation. This is precisely what occurs now with the need for companies to take back their products. Companies are facing nowadays a new scenario to which they have to react and within which they have to find the best practices in order to survive in the competitive market. Case study is one of the most adequate techniques to disclose the ways firms are handling and coping with this new challenge posed in the arena of the reverse logistics. Furthermore, by using case study we are contributing to expand its utilization within the Operations Management field, a field about which, according to Meredith (1998), only few case studies have been published[7].

  Six cases studies have been carried out, clustered in the thesis under three headings.

  The first one is a case analysis about the links between repair activities, reverse logistics and sustainable development. After a deep review of the literature focused on

[7] The assessment is also corroborated, as far as logistics are concerned, by the review study made by Mentzer & Kahn (1995). From the 235 logistics articles gathered, only 3.2% were performed by using the case study method.

these three topics, a comparative analysis between two different companies aimed to point out the key factors that explain the differences among them in relation to the development of repair activities and reverse logistics. Besides, how they may influence on the environmental performance in a company is shown. Some assumptions from this case analysis are drawn.

The aim of the second case study was to describe changes in purchasing patterns as a result of recovery and reverse logistics practices. If in the past, purchasing managers have been compelled to adopt new strategies to face different challenges encountered in normal business (competition, globalisation, periods of shortage, etc.), nowadays the increasing environmental concerns from both public governments and customers pose firms and, consequently purchasing executives the same need of looking for a new strategy. Manufacturers are forced to take back previously shipped products, in an attempt to reduce the amount of waste in landfills (e.g. from end-of-life items) or the consumption of resources in production processes (in case of returns from which some value is possible to be recovered). In the later case, firms come across a new source of components, parts or materials that need not be purchased. However, some degree of complexity arises when it comes to purchasing planning. For example, the uncertainty in supplies, inherent to the reverse process, is a unique characteristic of this scenario. Managers need to cope with the lack of information regarding quantities of returns and times when they will be recovered. On the other hand, not before disassembling the returned product is possible to know about the availability of certain components and without this information is difficult to order to suppliers within acceptable margins of error.

The study was carried out in two companies. Although the firms are still smoothly involved in recovery activities, some steps have been given forward to react to this new managerial demand. One important issue discussed is the need to accommodate traditional techniques for estimating purchasing orders (such as Material Requirement Planning) so that information regarding returns could be also taken into account. The

convenience for the firm to shift from no recyclable to recyclable materials and to modular designs, in order to facilitate the recovery process later and thus, the purchasing management, is also discussed. Another issue relates to the use of the information gathered from the returns as a supplier evaluation criterion.

Finally, the third case study aimed to go deeper in the relationship between the trend of going green and the degree of reverse logistics implementation. Since the awareness for environment and sustainability burst in the 90's, the progress achieved in this side has been remarkable, as some indicators may prove. Linked to the process of bigger environmental concerns, the irruption of reverse logistics has taken place. The bond between both processes (going green and reverse logistics) seemed to be inevitable in businesses since reverse logistics provides the logistics support needed for the desirable value recovery to be a reachable environmental goal. The magnitude that seems to be inferred from the most recent literature on the subjects pointed out a strong relationship. However, the real magnitude needs to be measured.

To this end, a leading European company was focused on and the reverse logistics practices adopted with two of its main customers were deeply analysed. From the study, some interesting results were obtained. For instance, the abovementioned relationship did not seem to be so strong, since even if companies are fully environmentally engaged, their reverse logistics implementation may still stand far behind. On the other hand, an important unbalance in the role played by the different recovery options was detected; legislation may be indirectly favouring this unbalance.

- The analytic hierarchy process (AHP) was the third methodology used in this thesis. From the previous six case studies, some determinants of the differences in reverse logistics implementation were detected. Their relative importance among a bigger sample of practitioners wanted to be analysed. The study attempted to verify the differences over different businesses and two different echelons in the supply chain (end product manufacturer, component supplier). Results emphasise the momentous

role played by customer pressure and characteristics of the product when decisions on reverse logistics practices are taken. Furthermore a link between the extent to which companies are involved in recovery activities and the degree of outsourcing reverse logistics processes is established.

Finally, Chapter 4 addresses the conclusions and suggests possible future lines of investigation.

Two final remarks need to be added:

- More interviews than the ones later commented in this document have been carried out. Addressed companies include several recyclers, distributors and third party logistics providers along with some additional manufacturers. The also valuable information gathered from the meetings may be diluted in the document but without specifically referring to those particular companies. The reason is sometimes the amount of information, not abundant enough to justify a separate section; some other times, the motive roots in the still scant significance of reverse logistics practices in their day-to-day operations.

- The results of the work reflected in this thesis have already been translated into several papers accepted and defended in six international conferences (NOFOMA in Oulu, ICPR in Virginia, CISIM in Poland, QMOD in France, RSC2004 in India, ICPQR in Miami); some articles have also already been sent to several international journals for their appraisal.

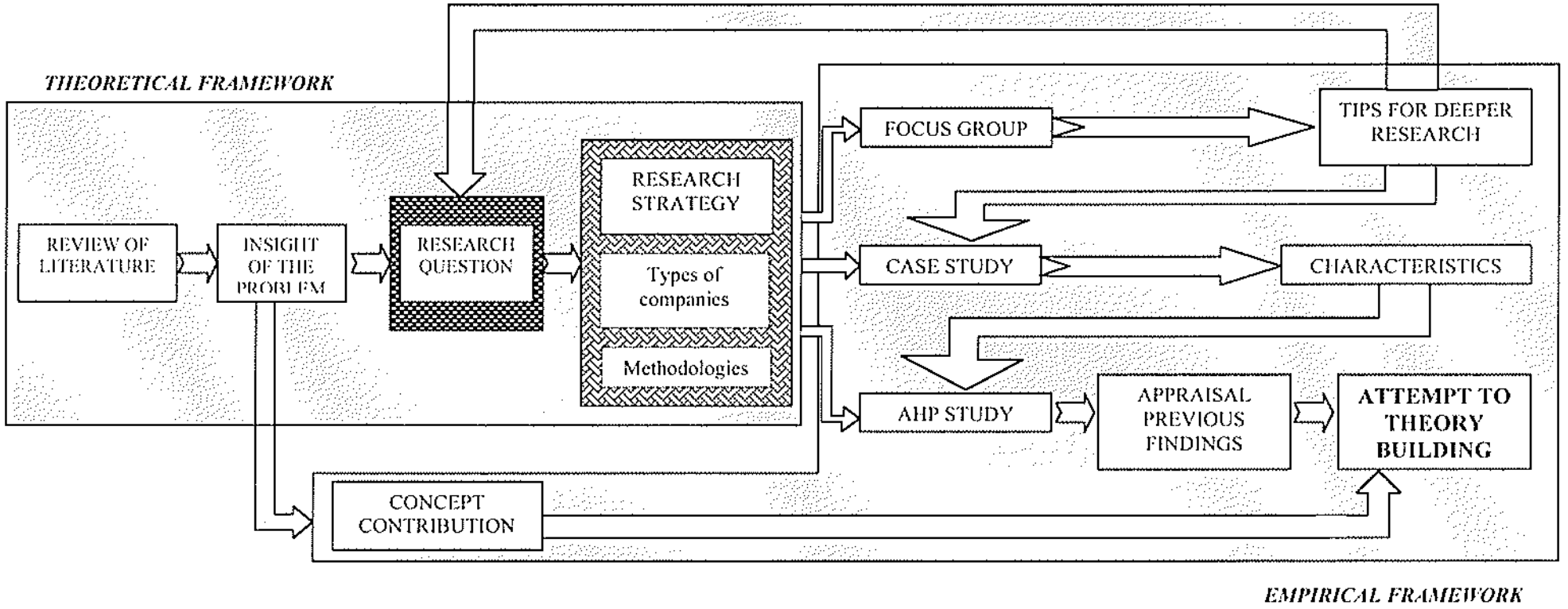


Figure 1. Outline of the research.

2. OVERVIEW OF REVERSE LOGISTICS

2.1. DEFINITION

2.1.1. INTRODUCTION

Reverse logistics is an issue that has received growing attention in the last decades, due to the occurrence and simultaneity of several situations. On the one hand, there is a verifiable concern about environmental matters and sustainable development. In this sense, there are several legal regulations that have been passed in a number of countries, Germany (with its obligatory taking-back of packaging materials and electronic devices regulations) and Netherlands (with its stringent automobile laws) being perhaps the pioneers. However, the effect has quickly spread out mainly along Europe, the USA and Japan.

On the other hand, economical reasons have also had their contribution in this increasing importance of reverse logistics issues. If operations are a major source of value-added (Porter 1985), by means of the returned products, companies stand the possibility of recovering either constituent material (that would not longer need to be purchased in the same quantities) or added value. Whether the savings come only from materials, labour or/and overhead costs, some firms have already shown increasing interest in being efficiently involved as market competition shrinks the margins more and more.

Perhaps due to its rapidly growing importance, the concept of reverse logistics has not been sharply defined. In fact, as several authors contend (Fleischman 2000; Mason 2002; Soto & Ramalhinho 2002; Kivinen 2002) and from the review of literature made, there is not yet a largely accepted consensus about defining reverse logistics in practice. There are also other broad topics feasible of being covered by it, such as activities, products, points in the supply chain, etc.

All the facets of reverse logistics are not a blur, however. As we shall see, definitions sometimes overlap in some of them. Some other aspects may be judged as giving only a partial vision, whereas in yet other cases, they may become controversial. For instance, if a vendor is not able to sell a certain product to the initially appointed market and then decides to send it to his own Distribution Centre, from where the unsold product may be resold to another vendor or broker who will try to sell it in secondary markets, should the whole operation be considered as "reverse logistics flow"?

The remaining part of the Section 2.1. is built as follows. In the next subsection, the above-mentioned idea is reinforced by definitions extracted from the review of recent literature. The sample of definitions chosen to be included from the existing literature does not aim at being exhaustive (more articles than the ones put forward were reviewed, although only the ones considered as most representative for the objective of the analysis and more quoted in literature were considered). By comparing the meanings provided by the different authors, the lack of an overall agreement becomes clear. The third subsection is then concentrated on the terms, which have been detected to be the main source for the different interpretations. In the fourth subsection some beliefs and misunderstandings are discussed before rounding off with putting forward a concept proposal in the last subsection.

2.1.2. REVIEW OF LITERATURE

Beckley & Logan (1948), Terry (1869) and Giultinian & Nwokoye (1975) had already paid attention to returns but without referring to them as reverse logistics flows. Murphy (1986) is arguably one of the first authors in using the basic concept of reverse logistics. He used Reverse Distribution as an equivalent term[8]; after him, the double terminology has also been kept in some cases (Pohlen & Farris 1992; Barry, Girard & Perras 1993; Bloemhof-Ruwaard, van Beek, Hordijk & Van Wassenhove 1995; Carter & Ellram 1998; Jayaraman, Patterson & Rolland 2003). Murphy defines Reverse Distribution (1986: 12) as " the

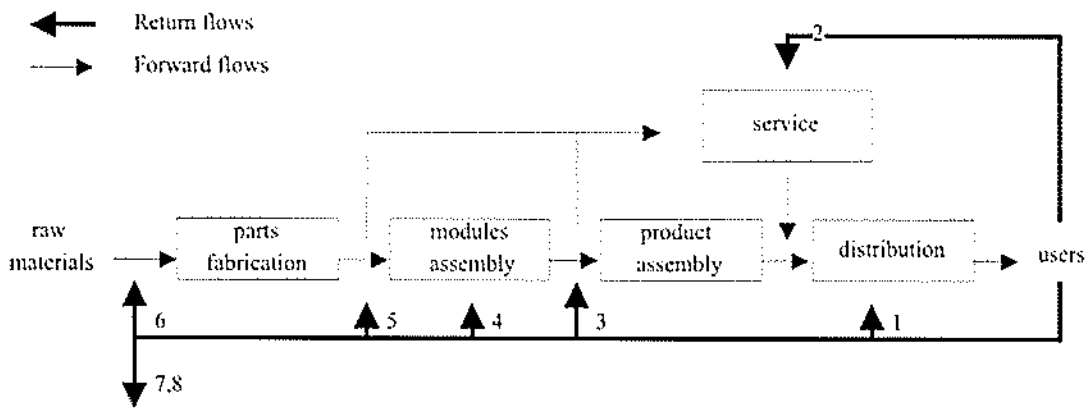
[8] According to Ballou (1992) Reverse Logistics is also referred as reverse distribution, due perhaps to the initial identification in the 1920s to 1960s between physical distribution and logistics.

movement of goods from a consumer towards a producer in a channel of distribution". Therefore, this author does already touch upon the backwards direction of flows in order for them to be considered as reverse logistics flows. Any good that may satisfy this condition is considered then as taking part in the reverse logistics flows. The original manufacturer is not necessarily the "producer" in this definition. As far as the distribution channel is concerned, nothing is specified in the definition. Doubts may arise between the two main possibilities to be distinguished: the referred distribution channel being the previously utilized (in the forward channel) or any other.

In 1992, Pohlen & Farris drew the attention to the fact that the recyclable material does not necessarily flow backwards through the same channel. The question that is raised now is what they meant by "recyclable". Is it so that only products whose destination is recycling (see Section 2.2.3 of this thesis for meaning of recycling) use different channels to go backwards? Or, are they using the word "recyclable" in a very broad sense of the term (meaning any product that can be returned)?

For Giuntini & Andel (1995a: 73) reverse logistics is defined as "an organization's management of material resources obtained from customers". With this definition, the authors skip the problem of stating exactly the direction taken for the material resources. Even more, they seem to stress just one aspect for a material resource flow to be considered as a reverse logistics flow; this unique feature refers to its origin. As long as the item comes from the consumer, the activities operated on it will be considered reverse logistics activities.

In the same year 1995, Thierry, Salomon, Nunnen & Wassenhove coin the term "Product Recovery Management" (PRM) to describe "all those activities that encompass the management of all used and discarded products, components, and materials that fall under the responsibility of a manufacturing company. The objective of product recovery management is to recover as much of the economic (and ecological) value as reasonably possible, thereby reducing the ultimate quantities of waste" (Thierry *et al.* 1995: 114).



Waste Management	Product Recovery Management		Direct Reuse
7. Incineration 8. Landfill	5. Cannibalisation 6. Recycling	2. Repair 3. Refurbishing 4. Remanufacturing	1. Direct reuse/ resale

Figure 2. Thierry *et al.*'s integrated supply chain view (1995: 18)

According to them, products and materials can be sent back either to the original manufacturer (therefore, in the same business chain), or to other companies involved in other business chains, provided the activity of these companies consist of manufacturing.

They distinguish three categories of activities: service, product recovery and waste management activities. Returned products and components can be resold directly, recovered, or disposed of (incinerated or put to landfill). Focusing only on recovery options, five different further alternatives can be found: repair, refurbishing, remanufacturing, cannibalisation, and recycling, listed in order of the degree of disassembly required [9].

Although it has to be noted that these authors did not use the term reverse logistics, a parallelism can be easily drawn from the mention of the activities included within the scope

[9] See Section 2.2.2. for their definitions.

of PRM and the direction followed by the recovered items in the Figure. Another conclusion from their work is that Direct reuse/resale, Incineration and Landfilling are kept out from the PRM coverage even if some backwards flow is also implied in these three options.

"Reverse logistics refers to the logistics management skills and activities involved in reducing, managing and disposing of hazardous or non-hazardous waste from packaging and products" (Kroon & Vrijens 1995: 56). This definition makes evident the extent to which, so far, confronting concepts can be found in the literature. If Thierry *et al.* have discarded waste management from their PRM definition, these authors seem to focus on it. Kroon & Vrijens' article is concerned with the flows generated by the returnable containers, which are a type of secondary packaging[10] in the sense that they are susceptible of being used more than once in the same form.

According to Stock (1998: 20), the term reverse logistics is used to refer to "the role of logistics in product returns, source reduction, recycling, material substitution, reuse of materials, waste disposal, and refurbishing, repair and remanufacturing". Although the majority of possible focuses, mentioned in the definition, have their correspondent translation in Thierry 's terms, Stock (like Kroon & Vrijens and unlike Thierry *et al.*) also emphasises the waste disposal aspect. Source reduction will be commented later in Section 2.1.3.4.

"Reverse logistics is a process whereby companies can become more environmentally efficient through recycling, reusing and reducing the amount of materials used. Viewed narrowly, it can be thought of as the reverse distribution of materials among channel members. A more holistic view of reverse logistics includes the reduction of materials in the forward system in such a way that fewer materials flow back, reuse of materials is possible and recycling is facilitated" (Carter & Ellram 1998: 85). The fact of reducing

[10] Secondary packaging is packaging material used for packaging products during transport from a sender to a recipient (pallets, slipsheets, etc), either in retail or in industry.

materials used in the processes is according to some authors (Rogers & Tibben-Lembke 1998) considered as "green logistics" and not "reverse logistics", although the same authors agree in that the boundary line between these both concepts is not always clear. On the other hand, the definition of Carter & Ellram seems to require the same channel in which the forward flow was generated, against the more broad view in which other companies outside the business chain could be favoured from the returns flows.

Krikke, Harten & Schuur (1999) mention the need for the European Original Equipment Manufacturers (OEM) to set up a reverse logistic system for their discarded products, which, according to the authors, involves determining an optimal degree of disassembly and assigning optimal recovery and disposal options. The OEM are in this case the point of destination for the return flows.

"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 or creating value or for proper disposal" is the definition of reverse logistics given by Rogers & Tibben-Lembke (1999: 2; 2001).

This definition is notably more ambitious, naming different types of items (no matter their condition of new or used) along with an idea of direction followed by the materials flows. However, solely the initial point of origin in traditional chain is accepted as destination of these reverse flows. When arguing the reason why source reduction, in their view, belongs more naturally to green logistics than to reverse logistics, they add the following (Rogers & Tibben-Lembke 1999: 3): "if no goods are being sent "backwards", the activity probably is not a reverse logistics activity". In spite of the comment, other possibilities are admitted within their particular reverse logistics scope, such as secondary markets, outlets ["(in the clothing industry) retailer's only sales alternative channel" (Rogers & Tibben-Lembke 1999: 82)], etc. even if these destinations are not the initial "point of origin".

The later remark also applies to the definition given by Dowlatshahi (2000: 143) when he contends that reverse logistics is "a process in which a manufacturer systematically accepts previously shipped products or parts from the point for consumption for possible recycling, remanufacturing or disposal". Therefore, he agrees with some previously mentioned starting and final points of the reverse flows, these being respectively the point of consumption and the original manufacturers. He differs however from other authors in discarding returns coming from other partners than consumers. Disposal is accepted to be within the scope of reverse logistics definition but secondary markets are not conceived within it.

Ritchie, Burnes, Whittle & Hey (2000) underline that logistics does not stop with the delivery of goods to customers, but also offers the opportunity for stocks to be returned to suppliers via a feedback loop. They point out the increasing frequency occurrence of product recalls appear to have in the last years in private sector (as their article examine the reverse logistics process within the Manchester Royal Infirmary Pharmacy; in this pharmaceutical arena, the efficacy in expeditiously withdrawing the drugs from market, in case of need, is critical). Their perspective drives the attention again on the suppliers as final destination of returned products and thus, endorsing the backwards direction of goods flows.

Fleischmann (2000: 6), one of the few authors aware of the confusion surrounding the concept, concludes that "the process of planning, implementing and controlling the efficient, effective inbound flow and storage of secondary goods and related information opposite to the traditional supply chain direction for the purpose of recovering value or proper disposal" is the content of reverse logistics. As he recognizes, municipal waste collection is not accepted within the definition's scope, as it does not concern flows opposite to the traditional supply chain direction. On the other hand, "upstream flow" substitutes the producer destination of returned goods stated in some other definitions.

"The logistics of return flows, called reverse logistics, aims at executing product recovery efficiently" (Hillegersberg, Zuidwijk, Nunen & Eijk 2001: 74). When the authors stress the

meaning of return flows they only admit end of life (EOL) products either for customer use, or for obsolescence in the forward supply chain. Apart from the activities included by Thierry *et al.* (1995) within the PRM, Hillegersberg *et al.* (2001), unlike them, admit also energy recovered by incineration in the definition. The list of products susceptible of returning is in this case more restricted.

A research report by Kivinen (2002) brings yet another perspective. He writes that different service providers must have different types of reverse logistics concepts. For instance, some companies may speak only about the recycling of goods, which may actually include sophisticated features of reverse logistics. His piece of advice is therefore to define clearly, between the parties involved, how reverse logistics will be understood in their relationships, as different persons will most probably have different views about reverse logistics.

To conclude this review, one more definition from the reverse logistics Executive Council[11]: "Reverse logistics is the process of moving goods from their typical final destination to another point, for the purpose of capturing value otherwise unavailable, or for the proper disposal of the products".

Next section summarizes the main confusing terms detected from the review of literature.

2.1.3. SOME CONFUSING TERMS

The confusion detected in the definitions may be mainly due to some words that may have a close meaning in certain contexts or double meanings of the words. In an attempt to create a less arguable definition for this work, we must also discuss the following in more detail:

- what does "backwards" direction mean,

[11] http://www.unr.edu/coba/logis/page6.html

- are reverse flows equivalent to flows of returns,
- are recovery and reverse synonyms,
- what is the difference between green and reverse logistics, and
- what position do disposition, recall and recycling have?

2.1.3.1. BACKWARDS DIRECTION

In accordance to the previous section, it is quite clear that no unanimity exists regarding the direction products must take in reverse logistics, once they abandon the forward supply chain, which may happen at any point/time within it. Some authors (Carter & Ellram 1998; Dowlatshahi 2000; Ritchie *et al.* 2000; Guide, Jayaraman & Linton 2003) call a flow "reverse" whenever the direction of flow is exactly the opposite (solid black straight arrows in original channel in Figure 2) to the forward one used by the product in its trip to the final destination. That means the product comes back through the same channel, sent by a downstream supply chain partner (e.g. from retailer to distributor, from distributor to manufacturer, from consumer to retailer or to manufacturer, etc.).

Other authors, however, admit the deviation of these returned products towards different channels (solid black curved arrows in Figure 2) as susceptible of being also considered as reverse logistics (Thierry *et al.* 1995; Fleischmann 2000; Reverse Logistics Executive Council). Recycling activities provide with a myriad of cases that are within this second broader sense "reverse", given that, on the one hand, recyclers interested in materials may be different from the original manufacturers (about all in secondary recycling, explained later). On the other hand, original manufacturers may not dispose of the specific equipment required for recycling.

This facet of the definition of Reverse Logistics, still unclear (as it was shown in the previous literature review), has straightforward consequences on the conclusions drawn from the research contain in those publications (conclusions about sectors of activity, management, vertical integration, etc.).

2.1.3.2. LOGISTICS OF THE RETURNS VERSUS LOGISTICS OF REVERSE FLOWS

Reverse logistics may refer to flows in reverse, that is, flows of goods that go in strictly backwards direction through the channel (solid black straight arrows in original channel in Figure 2). However, another more ample perspective was found in the literature (Fleischman, Krikke, Dekker & Flapper 2000; Stavros, Costas & Theodore 2003), which refers to the management of returns not only in backwards direction but also, in forward direction once returned products have been transformed (repaired, remanufactured, etc.) and again come back to the markets (dotted green arrows in Figure 2). In this second sense, all operations where products, once having been returned, are involved are also considered within the reverse logistics scope.

Both perspectives coincide in considering Reverse Logistics flows those that are sent backwards along the supply chain (for instance, from end consumers to manufacturers). However, there is an obvious disagreement with regard to accept as Reverse Logistics activities those performed in order to send to the markets returned products already transformed.

2.1.3.3. RECOVERY VERSUS REVERSE

Polemic is also caused by the terms "recovery" and "reverse". Etymologically speaking, the concepts of recovery and reverse are not equivalents. According to the dictionary, the term recovery has its roots in the Latin term "recuperare" which means, "to take". However, the term reverse is the past participle of the Latin term "reversus" which means, "to turn back". From the previous meanings, it may be easily inferred that the signification of the term recovery is noticeably more ample than the one inferred from the term reverse. It could summarily be illustrated by stating that not all that is "taken" has to or needs to be "turn back".

In spite of their different meanings, both seem to be, in certain pieces of work, considered synonyms (as it also happens with a third term: "return"). As an example of the interchangeability of these terms in practical use, let us recall the definition given by the European Working Group on Reverse Logistics (Revlog) about reverse logistics. According to Revlog[12], "Reverse logistic stands, in a broadest sense, for all operations related to the reuse of products and materials. The management of these operations can be referred to as Product Recovery Management." Using Reverse Logistics Management instead, the misunderstandings introduced with the term Recovery could have been avoided.

An attentive and detailed reading brings a more global scope to the term "recovery". Within recovery sense, a greater number of activities may be included than under the definition of reverse logistics.

2.1.3.4. GREEN LOGISTICS VERSUS REVERSE LOGISTICS

Although these two terms have already been mentioned, it is worth to devote to them a special thought.

The increasing number of laws being passed mainly in the last decade with regard to the environment protection has been remarkable. Both the sheer number, but also the laws becoming more stringent and demanding, may well have had a considerable influence for the terms "green logistics" and "reverse logistics" being likened perhaps without a sound basis. The fact that environmental management is drawing growing attention among researchers and practitioners (not only from supply chain management field), is something that can easily be verified. In this vein, Handfield & Nichols (1999) underline the seminal role that the "green" issues will play in the future of this field. On the other hand, the survey carried out by Murphy, Poist & Braunschweig (1994) showed how 60% of the managers interviewed considered environmental issues to be very important in the business

[12] http://www.fbk.eur.nl/OZ/REVLOG/

of their companies. These examples serve to demonstrate the increasing weight of green issues nowadays.

However, van Hoek (1999) contributes with his article to avoid mixing up reverse logistics with green logistics. The term "green logistics" is coined to refer to those practices within the supply chain that aim at reducing sources of waste and resources of consumption. They are not necessarily specific of reverse logistics processes. For instance, disassembly is an operation closely related to reverse logistics; it is critical before deciding, in many cases, what to do afterwards with the product (repair, remanufacture or recycle it). However, it will be only linked to Green Logistics in the design process if the disassembly operations are carefully thought for not going through destructive operations, which implied at least a lost of added value if not also materials. Furthermore, some forward logistics processes from original manufacturer to original customer could be also "green".

2.1.3.5. RECYCLING

Next, the focus is on just one of the options that have widely been accepted to lie within the scope of Recovery options, the recycling. In the paper by Lave & Hendrickson (1999) the lack of an agreement in U.S.A. when it comes to decide what constitutes the so called Recycling of Municipal Solid Waste (MSW), or which part of the post-consumer waste has to be included in it, is highlighted. The agreement has not been reached in spite of the efforts carried out by the Environmental Protection Agency (EPA).

As already pointed out in the introduction of the Definition section, the use of the term "recycling" may be a source of misunderstandings. The most commonly accepted meaning is that recycling implies the fact of recovering materials, which take part in the composition of the recyclable product. Recycling therefore involves the higher degree of disassembly of the item. However, it is not unusual to come across a more general use of the term that implies any activity in the backwards process or any reusing option (see Pohlen & Farris II 1992; Guide *et al.* 1997; Azzone & Noci 1998 as some examples). The European

Commission, in preparing its proposal for the 6th Environmental Action Programme, is already conscious and is faced with the same problem: "We also want to develop a better definition –feedstock is considered recycling in some member states but as energy recovery in others-: a classification is needed" (Villalba, Segarra, Fernández, Chimenos & Espiell 2002).

Recycling has been the target of quite a few acts, the EU Directive on Packaging and Packaging Waste 94/62/EEC being perhaps the one with broadest impact. The Directive addresses the need to conform to the EU waste management hierarchy, i.e. to minimise the generation of waste and to increase reuse, recovery, and recycling of waste (although no consensus exists either in how to measure this recyclability). The Directive sets recycling and recovery targets[13], which must be achieved by specific deadlines.

It must be said that when the Directive refers to recycling, two different kind of recycling meanings (not always familiar in common use) have been used. These are primary recycling[14] and secondary recycling[15]. But the Act also mentions the term of "recovered" in the first target. In this context, recovery means "any of the applicable operations provided for in Annex II B of Directive 75/442/EEC" and the recovery options listed in this Annex are: "use as fuel, recycling, recovery of components (used for pollution abatement or from catalysts), and land treatment". This perspective of the recovery options is much more restrictive than the one used by scholars and practitioners, as already discussed in Section 3.1.1.3.

---

[13] In the implementation of the Directive, two of the three objectives are stated as:

- "not later than 5 years from the date by which this Directive must be implemented in national law, between 50% as a minimum and 65% as a maximum by weight of the packaging waste will be recovered.
- within this general target and with the same time limit, between 25% and 45% (by weight) of the total amount of packaging materials contained in packaging waste will be recycled, with a minimum of 15% by weight for each packaging material. "

[14] Primary recycling means that the constituent material of a product can be transformed into a product on the same value-level as in the first cycle of its usage (e.g. the glass recovered from glass bottles may be used to produce glass bottles again; recycled gold value does not decrease along with recycling times).

[15] In secondary recycling, recovered materials are used for lower-value applications (e.g. polyurethane foam material from car seats can be transformed into carpets under-layers).

The concept of recycling usually is, on the other hand, timely linked with the final stage of the product life cycle, i.e. when the final consumer discards the product. But recycling may also take place at any other stage of the life of the product and that is the reason why the term of "pre-consumer recycling" has been coined referring to the recycling that may occurs during the manufacture of the product. In fact, the data, from Greenpeace confirms not only the fact of residuals are produced at more points than the one corresponding to the final consumer but also, the importance of the Figures and consequently the need for a solution which according to their words should be to foster the recycling. According to these Figures, for each ton of waste generated at the end of the supply chain there are another five tons created during the manufacturing process and another twenty in the extraction point.

2.1.3.6. DISPOSITION

Looking up the term "disposition" in the dictionary provides with two different meanings that apply in the present context:

1. The act or means of getting rid of something. In this case, the word disposition is taken as a synonym of the term disposal. Therefore, if the company should decide the disposition of its products, it should determine the final destination for the items. The two options within this kind of disposition will be incineration or landfill.

2. The state or the manner of being arranged (Meyer 1999; Krumwiede & Sheu 2002). Words such as arrangement will be considered as equivalent. The alternatives for a company included under this second meaning are more numerous ranging from repairing, remanufacturing, refurbishing and recycling, to reselling or disposing of the product (in the first sense).

The use of the word "disposition" may then seem a bit tricky if the context does not provide further hints to distinguish between the two mentioned meanings. A company may

"dispose" a product in the second sense without, at the same time, "disposing of" it in the first meaning. This leads to definitions such as "at the simplest level, it [reverse logistics] can be described as the disposition of returned goods" (Tan & Kumar 2003), which basically can lead to reverse logistics flows being no flows at all. The remark on the utilization of this word does not intent to be critical with the users. Actually, the word has been correctly used by all of them. However, given that the meaning may be quite different depending of the context, it would be advisable to choose it only when the sense does not drive to ambiguities or misunderstandings.

2.1.3.7. RECALL

Recall is one of the motivations one product may be returned for in the supply chain (although it is not an reverse logistics activity).

Recall is also a confusing term. Sometimes the word recall is used to refer the reverse process of consumer goods, which could potentially endanger the customer. Efficient recall strategy is, in this sense, concerned with minimising public risk, getting back as many faulty products as possible and minimising cost and inconvenience for the customer and the company (Smith, Thomas & Quelch 1997; Rogers & Tibben-Lembke 1999; Ritchie *et al.* 2000; Muffatto & Payaro 2003). However, the term may be also found implying a more general perspective; in this case, recall a product equals to repossess the product by the manufacturer (Jayaraman *et al.* 2003).

2.1.4. DISCUSSION

The fact of a product coming from the end of the traditional logistics chain, that is, from the consumption point does *not* entitle it straightaway as an item belonging to the reverse flow chain. Not all products provided by the consumer take part of the backwards channel. One example could be the following: one consumer does not longer require a product, and

consequently he decides to put in motion a process of sale by his own by means of e-commerce (e-commerce makes nowadays, at least theoretically, this possibility be accessible to anyone). Another consumer acquires the item. This operation has had no backwards direction at all; therefore, in our view, there is no sound reason to call it reverse logistics.

On the other hand, it is *not* absolutely required to be part of the reverse logistics chain that a product, which is taken the backwards direction in the channel, has been initially sent backwards by the consumer. Different participants involved in the chain might, at any moment, send back the products.

A third characteristic is that reverse logistics products do *not* have to be "used" neither must to have reached their end of their usable life (EOL). A defective product sold to a consumer or even detected at the retailer store before being sold may be sent back to the manufacturer to be repaired, without having been used and consequently, with the faintest possibility of having exhausted its life cycle. For instance, a product damaged in transit from the manufacturer warehouse to a distribution centre does not satisfy either of the two conditions (being used or an EOL product).

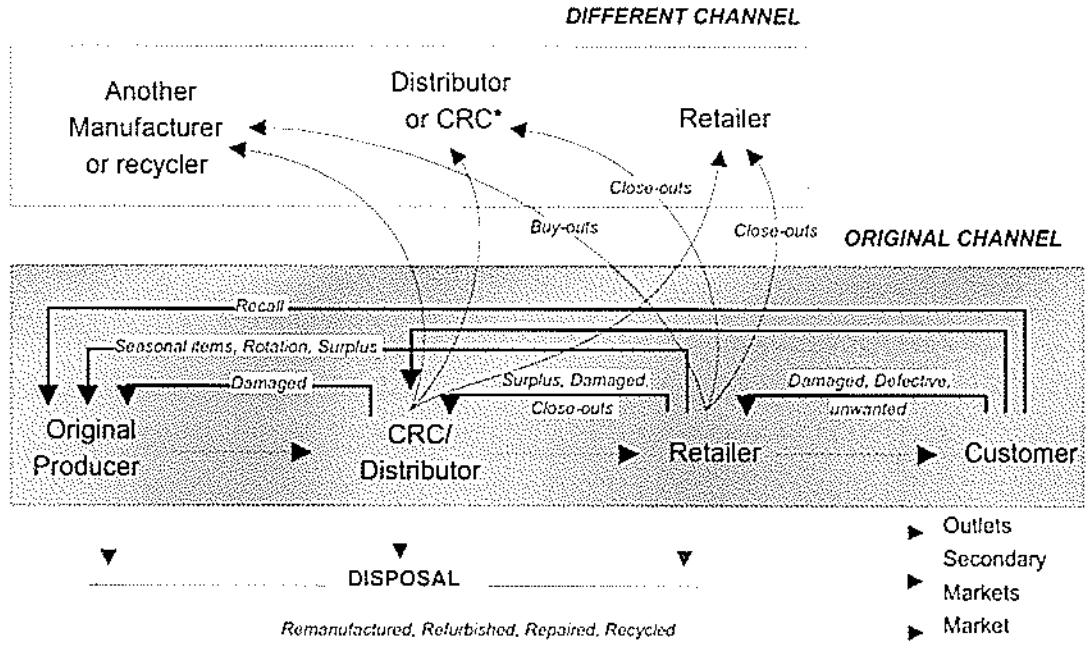
Within the reverse logistics lexicon, the most important words begin, according to Giuntini & Andel (1995b) with "R". One of this "R" stands for Re-engineering (the rest are Recognition, Recovery, Review, Renewal and Removal). Re-engineer the reverse stream implies, for these authors, to reduce (one more R) the amount of material, which will end up as waste. And, indeed (as stated in the introduction), one of the perhaps most powerful drivers for the implementation of reverse logistics practices has been the problem generated from waste; waste is nowadays an important problem in many countries due to the increasing volumes and the lack of landfills where to dispose of it (Fernández 2003c). However, reverse logistics activities are *not* directly concerned with reducing waste or/and reducing the need for raw material (as green logistics may be), although these reductions may be side effects of adopting them.

2.1.5. CONCEPT PROPOSAL

Given the previous disparate views of the reverse logistics definition, this author feels that the time to reach a unanimous agreement on the scope of this discipline has come. Up to now, and although some researchers noticed it before and did some comments in passing, no article has been strictly devoted to try to clarify the concept neither to draw the attention of the rest of the community working on the subject of reverse logistics.

As stated by Fleischmann, Bloemhof-Ruwaard, Dekker, van der Laan, van Nunnen & van Wassenhove (1997), products may return to its original producer or may be diverted towards a third party. In fact, it seems to be verified that it is common practice to carry out remanufacturing activities in-house whereas recycling is more often being performed by specialized companies (Thierry 1997).

Figure 3 shows, indicated by arrows all the possible movements a return product may follow. The dotted arrows (in the original channel) represent the traditional forward logistics flows used by new products. The dotted arrows (outside the original channel) stand for several ways the returned items may take, once the required operations have been performed on them.



*CRC: Centralized Returns Centres

Figure 3. Different issues for returns.

There is no polemic approach in considering the solid straight arrows as reverse logistics. All of them represent backwards flows within the original channel through which the product was originally sent to the market. The conflict appears when looking at either the curved arrows (i.e. when other channels are involved) or the dotted arrows (representing returns already reprocessed in most of the cases, disposed of or deviated to another markets).

If we think, for instance, on the retailer from the original chain and we think that a product has been sent back to this retailer from his customer with the package intact (because the customer did not open it), and the retailer decides to sell it to another retailer, who may be able to sell the product to another customer or market, the prime retailer could be seen as a wholesaler regarding the second retailer, and the idea from here on still is about the forward chain. Nothing goes back from the retailer on in this flow case.

A similar case is posed when coping with buy-outs. Buy-outs, according to Rogers & Tibben-Lembke (1999), happen in logistics sense, when one manufacturer purchases a retailer's entire supply of a competitor's goods. If a manufacturer from another channel buys from the retailer this kind of stocks, again the retailer could be seen as another middleman in the channel. Items from the shelves of retailer's facilities go to another destination (manufacturer in lieu of customer). Unlike the previous case, there is a movement, which could be seen as backwards if the partners in chain are thought in the order manufacturer-distributor-retailer, but not within the same channel neither with materials or added-value recovery aims (plain competition driver).

Something different happens when this manufacturer happens to be a recycler. The recycler needs the return of the product in order to get access to its constituent parts and materials. Recyclables may have their origin in household waste (final customers who discard products for one reason or another), retailers, distributors or the very original manufacturer. The recycling was not the original destination for the product, which was aimed at reaching the market where the final customers would use it. In this case, there is indeed an intention of recovering materials.

On the previously discussed basis, reverse logistics is proposed to be defined as:

The management of any type of items (used or not, finished products or just components, parts or materials), which, for different reasons, are sent by one member of the supply chain to any other previous member of the same chain. In addition, flows taking place out of the original chain, whose origin is located in the original supply chain, are also included provided they are consequence of activities of repairing or recovering added value or material.

2.1.6. CONCLUSIONS

A comprehensive review of the literature from the last decade drove to appreciate the lack of a not widespread accepted concept of reverse logistics. The sample of definitions collected here do not, in general terms, contradict themselves. In fact, all of them refer to the same process, although, from them, one seems not to be able to draw strict conclusions either to the products that may take part in the reverse logistics flows nor their ultimate destinations. After analysing the different definitions and applications (type of work not found hitherto in the literature reviewed), some blurred terms, ill defined and even, in a few cases contradictory, visions were detected. An attempt of disclosing the sources of possible misunderstandings was followed, as final contribution, by a proposal of a concept, kept at the same time, concise but comprehensive.

In what seems to be no conflict at all is the acceptance that, in a market situation like the one the companies have to face nowadays in which issues such as product quality, competitive price, customer service, and fulfilment of due times are, among others, factors already internalised by the majority of companies, the reverse logistics is set up as the last differential element, the competitive advantage, the key question with which to go further in efficiency and as possibly the last frontier to achieve the goal of reducing costs.

2.2. REVERSE LOGISTICS DIMENSIONS

2.2.1. TRIGGERS IN REVERSE LOGISTICS IMPLEMENTATIONS

The development of recoverable manufacturing systems has been driven by one or more of the reasons (Guide, Jayaraman, Srivastava & Benton 2000; Tan & Kumar 2003; Tan, Yu & Kumar 2003) explained briefly in the following.

Legislative mandates: In the last decades a great number of acts have been passed regulating the amount of products to be put to landfill and stimulating different levels of

reuse. The path to full harmonizing and consensus among countries regarding the terms has not been effortless, as Cairncross (1992) points out. However, several European countries have already dictated and passed laws making (and even prohibiting in certain cases) the dumping of industrial residuals and scrap more difficult. These laws also substantially increase the costs derived from their disposition and appoint the manufacturer as the final responsible for his products. In Europe, some examples can be mentioned. In Germany, a stringent policy addresses nowadays the packaging material. Furthermore, in The Netherlands white and brown goods are regulated (Fleischmann, Beullens, Bloemhof & Wassenhove 2001). Other examples may be found in the rest of the world: automobile sector is regulated in Taiwan, as the electronic equipment and durable goods sector is in Japan (Inoue 1994). USA, Canada, Korea are countries where government action has also been notable.

Among the different policy tools considered by public institutions, the following options can be found: voluntary agreements or covenants with industry to achieve waste targets, deposit refund schemes, product disposal charges, end-of-life take-back requirements, eco-labelling, etc. (Gertsakis, Morelli & Ryan 1998).

The reaction of corporations to these legislative requirements has not been uniform. For example, the car industry seems to have taken, at least in principle and with some notable exceptions like BMW for instance, a defensive stance. This attitude consists of observing the passed laws, above all those dispositions characterized by increasing in the least their costs.

Growing environmental concerns both among the consumers and the businesses. "Environmentalism has been characterized as the most significant force shaping the economy, as well as the most important issue facing business during the 1990s" (Murphy *et al.* 1994: 90). On the one hand, to achieve a "green image" may produce important profits and good market share, since some customers will see satisfied their exigencies in this field. The implication of some member of the supply chain in environmental initiatives spur and

drag other member too. One example of it is the increasing number of companies that adhere to international certification standards such as ISO 14001, and EMAS (Eco-Management and Audit Scheme); see, for example, Melynk, Stroufe, Montabon, Calantone, Tumala & Hinds (1999) or da Cuna & Giacomucci (2002).

Environmentalism and logistics are closely related and influence each another. Environmental issues are a factor to be considered nowadays when adopting logistics decisions of different kinds, e.g. facility location, sourcing of materials, transport means, etc. (Wu & Dunn 1995). One of the impacts of the environmentalism on logistics management is to broaden the scope of logistics from the perspective of forward distribution to reverse distribution; return goods handling emerges as one of the three most impacted logistical functions (Murphy *et al.* 1994). At the same time, logisticians "are best able to influence and/or manage environmental issues dealing with pollution, the conservation of resources and congestion" (Murphy & Poist 2003).

Profitability. Even if responsibility faced by manufacturing firms for complying with product take-back policies forced them to assume certain kind of costs i.e. disposal costs (Klausner & Hendrickson 2000), profits may also be derived (Ayres, Ferrer & Van Leynseele 1997) from several sources, such as:

- A smaller amount of new materials required for production, as not only materials but also added value have been recovered. The cost of purchased parts and components is a very large fraction of direct manufacturing costs (Ayres *et al.* 1997: 557); returns may represent a cheaper source of items.
- Reduction in landfill and disposal costs (another cost element that has been increasing very rapidly, partly because scarcity of landfill sites and partly because the increase in costs of those landfills still in operation),
- Better market share as a consequence of a better environmental image,
- Reduction in pollution taxes as gaseous and solid pollutants are reduced,
- Reduction in the energy consumption (as it is shown in the following table).

Table 2. Comparison of energy consumption (Faltermeyer 1972).

	Steel	Aluminium	Cooper
Energy required in pounds of coal to produce one pound of material			
* from virgin ore	1,11	6,09	1,98
* from recycled materials	0,22	0,17-0,26	0,11
Percent reduction in energy requirements with recycling	80	96-97	94

The data offered by Lund (1998) with regard to the 73.000 companies in remanufacturing businesses only in United States gives an idea of the economical importance of this activity.

Market forces. Reverse logistics can be used to free customers from obsolete or slow moving inventories so that they can buy newer goods with a capital otherwise captive (Andel 1997). It benefits also the supplier who is able to, firstly, give rotation to new launches and, secondly, get information about market trends and react accordingly. On the other hand, order cycle times have dramatically declined (Montgomery, Manrodt & Holcomb 2002); Reverse logistics may also contribute to deal with this new requirement of the market.

Shortening product life cycles. Apart from the globalisation and fierce competition, one feature that characterizes actual markets is the shrinkage in product life cycles. Computer industry stands for a good example of it. Markets mature quicker than they used to (Christopher 1997) and new designs are brought on to them at an ever-faster pace (Tan *et al.* 2003). The price for consumers enjoying a greater variety and choice of products as well as improved performance is the increased amount of unsold products, returns, packaging materials, and more waste (van Hoek 1999).

Therefore, shorter product life cycles have increased both the volume to be dealt with by reverse logistics networks and, also, the cost of managing them (Giuntini & Andel 1995a).

Extension of logistics services gamut. O'Sullivan (1997) surveyed 300 multinational companies operating in Europe about their expectations in logistics. According to the survey, the most important factor influencing development in European logistics is the demand by customers for improved levels of customer service. Customer service, when utilised effectively, is a qualifier for competitive survival (Cohen, Heng & Agrawal 1997) and a key factor in creating demand and retaining customer loyalty (Kyj & Kyj 1994). Companies, aware of it, strive for keeping their actual customers faithful to them and for attracting new ones. According to Sum & Teo (1999), logistics management is strongly focusing on customers. A strategy adopted in some organizations consists of differentiating their products or services from their competitors. The offering of new logistics services, such as return allowances, is a factor some segments of customers will react to in a positive way.

New direct channels of distribution. New channels render different and more agile modes of acquiring products from markets (Tan *et al.* 2003). However, direct channels (like e-commerce) add pressure on the reverse logistics activities (Autry, Daugherty & Richey 2000) as they increase the likelihood of returned products, as a result of damages in transit, abuses from customers, etc.

New source of information. Although from the review of the literature, this driver does not seem to be important enough to persuade a company to be involved in the reverse logistics activities, it is indeed a side effect that should not be ignored. Doubtless, a first hand information about a product that is not being sold as expected, permits the company to quickly react to this fact and increase its activities to the market.

Finally, a last driver could be added, perhaps of not easy quantification in monetary terms but, not for that less important; the absolute *self-satisfaction* of knowing that, independently of external pressures or conditionings but by own decision, the activity undertaken by the company is contributing to maintain the state of the environment or even to improve it. The fact of being able to reduce water consumption in steel industry, to restraint the emission of air-pollutant residuals in a chemical industry, or to streamline the use of raw materials in a

paper industry, are reasons with enough importance so as to consciously orientate processes to recovery. As an example let us have a look to the following piece of information: a ton of paper from recycled pulp saves at least 14 trees, three cubic feet of landfill space and 7.000 gallons of water. Fibres can be reused 4 or 5 times before it is no longer suitable for paper manufacture. (Anonymous 2000)

This, let us call it, satisfaction is the same as the one some authors (Elkington 1994; Dowlatshahi 2000) attribute to those final consumers who will be willing to pay a bigger price for the products, if they knew for sure that by doing so, both the society and the environment would benefit. This kind of altruistic behaviour found in final consumers has not yet been reinforced empirically to exist in companies. Participants in a survey carried out by Knemeyer, Ponzurick & Logar (2002) argue that the environmental benefits did not represent enough appeal to use recycled or refurbished products in their companies.

A corporation that manages to satisfy the legal requirements, at the same time favouring the environment, succeeding moreover in positively meeting the expectations and demands of its customers, and being finally able to get improved results as a consequence of its actions, is definitely running a win-win-win strategy (Maslennikova & Foley 2000).

2.2.2. TYPES OF ITEMS TAKING PART OF RETURN FLOWS

The items that may be object of taking part in the material flows of the reverse logistics process are:

- Scrap: residues left from production processing.
- By-products: products obtained during the manufacture of the principal product.
- Waste: surpluses from the inefficient use of production machinery, carelessness and poor purchasing.
- Obsolete products or equipment.

- Damaged stocks or equipment: sent backwards whether in exchange cores contract terms (organization sends rebuilt unit and customer sends broken unit), or for repairs and/or remanufacturing, for inspection and/or recalibration (i.e. safety regulatory mandated calendar time requirement) or for product upgrades (Lamar & Dobler 1995).
- Return goods for credit.
- Return goods due to commercial agreements (supplier/retailer or retailer/customer i.e. warranty returns).
- Short-term rental returns.
- Long-term lease returns.
- Reusable containers (Kroon & Vrijens 1995).
- Take-backs (the best known relating to packaging materials (see an example in Bloemhof-Ruwaard, van Nunen, Vroom. & van der Linden 2001)).
- Recalls: a production error, a design failure or even a case of deliberate sabotage may cause the need to isolate and return all units of a given production lot to ensure the safety of the consumer (Giuntini & Andel 1995a).
- End-of-use returns[16]: denote flows of goods that are disposed of after their use has been completed. They typically originate from customers (Fleischman 2000: 20).

Table 3 summarizes some industries were reverse logistics studies have been already carried out.

[16] End-of-life in some texts, although they are not exactly equivalent terms.

Table 3. Industries focused by reverse logistics literature.

Personal computers	Ashayeri, J., R. Heuts & A. Jansen (1999)
	Knemeyer A., T. Ponzurick & C. Logar (2002)
	Krikke H., A. Harten, P. Schuur (1999)
	Fleischmann, M., J. van Nunen, J. & B. Gräve (2002)
	Tan, A., W. Yu & A. Kumar (2003)
	White, Ch., E. Masanet, Ch. Rosen & S. Beekman (2003)
Vehicles	Bellmann, K. & A. Kahre (2000)
	Purohit, D. (1992)
Packaging & containers	Bloemhof-R., J., J. van Nunen, J. Vroom & A. van der Linden (2001)
	Del Castillo & Cochran (1996)
	Duhaime, R., D. Riopel & A. Langevin (2000)
	Giuntini, R. & T. Andel (1994)
	Kroon L. & G. Vrijens (1995)
Carpet	Ammons J., M. Realff & D. Newton (1997)
	Louwers, D., B. Kip, E. Peters, F. Souren & S. Flapper (1999)
Power tool	Klausner, M. & C. Hendrickson (2000)
Electronic equipment	de Ron, Ad. & K. Penev (1995)
	Fleischmann, M.; Beullens, P.; Bloemhof, J.; Wassenhove, L. (2001)
	Maslennikova, I. & D. Foley (2000)
Domestic appliances	Krikke H., J. Bloemhof-R. & L. Wassenhove (2003)
Paper	Madu, Ch., Ch. Kuei & I. Madu (2002)
	Fleischmann, M.; Beullens, P.; Bloemhof, J.; Wassenhove, L. (2001)
Plastic	Pohlen, T. & M. Farris (1992)
Medical equipment	Ritchie L., Burnes B., Whittle P., Hey R. (2000)
	Rudi, N. (2000)
Batteries	Stavros E., P. Costas & G. Theodore (2003)

2.2.3. RETURN FLOW OPTIONS THAT REQUIRE AND JUSTIFY THE EXISTENCE OF REVERSE LOGISTICS

The options why a product may enter the reverse logistics channel can be categorized in three main different groups: i) those, which extend the product life span, ii) those, which allow an enlargement of the material life cycle and iii) other options.

i) Options that span product life

a. Direct reuse: apart from some cleaning or minor maintenance, neither materials, nor parts are replaced. The product is put into available usable stock "as is". This option may fit unsold seasonal clothes re-sent to secondary markets. It is also applied to returnable containers, crates or refillable bottles used, for instant, in dairy sector and/or in soft drinks.
b. Resale or transfer the ownership (Giuntini & Andel 1995b). This option can be included also in the second category (material life-cycle extension).
c. Repair: it implies to restore failed products to "working order", though possibly with a loss of quality.
d. Refurbishing: Although Thierry *et al.* (1995) consider this option with enough entity to deserve a special denomination, some authors include it within the following one of remanufacturing (Guide, Kraus & Srivastava 1997). The option of refurbishing implies more disassembly than repairing. Its purpose is to bring used products up to specified quality and, eventually, technologically upgrading them, by replacing outdated modules. A five-year old computer may gain in processing speed or in memory just installing a new module in its configuration.
e. Remanufacturing: "industrial process in which worn-out products are restored to like-new condition. Through a series of industrial processes in a factory environment, a discarded product[17] is disassembled completely. Usable parts are cleaned, refurbished and put into inventory. Then the new product is reassembled from the old and, where

[17] Although Lund (1983) seems to focusß only on discarded products, Guide et al. (1997) contend that a product does not have to be discarded in order to be considered for remanufacturing.

necessary, new parts to product a unit fully equivalent, sometimes superior, in performance and expected lifetime to the original new product" (Lund 1983: 19).

f. Upgrading: products undergo some operations aiming at giving them not only original functionality but also new features. Sometimes in the literature, this option is included in refurbishing and remanufacturing option.

ii) Options that extend material life cycle

a. Cannibalisation: it implies to selectively disassembly and recover, from used products or components, a limited set of reusable parts, which may be reused in repairing, refurbishing, or remanufacturing of other products and components (see Rudi, Pyke & Sporsheim 2000 for an example). The result may be the achievement of some savings stemmed from the fact that the company does not need to buy or produce these parts although other costs are playing in (labour cost of the selective disassembly, storage of the remaining unwanted parts, the disposal of those, etc).

b. Recycling denotes material recovery without conserving any product structures (Fleischman 2000). It may be primary or secondary recycling[18]. From an environmental perspective, recycling is always a preferable solution when compared to the disposal options (Jahre 1995: 39). However, recycling may be capital intensive for certain goods (i.e. some voluminous durable assembly products) (Krikke, Harten & Schuur 1998); consequently and from an economical standpoint, recyclables should be able to compete with primary materials both in price and in quality (Bellmann &Khare 2000).

iii) Other options

When any of the previously listed options is eligible, only one remaining option is left: disposition. Disposition usually implies one of the following forms:

a. Incineration (sometimes referred as "energy re-use").

b. (Open or protected) landfill disposal.

[18] See Section 2.1.4.5. for definitions.

In many situations an old product can be reused in different ways, each yielding different costs and profits: upgrading, pure restoring, disassembly and reuse major modules, and so on. These options are mutually exclusive and differ with respect to the costs incurred during the reprocessing and the revenues generated by each option. The selection of these options is one of the main Operations Management problems associated with recovery issues (Inderfurth, Kok & Flapper 2001: 131).

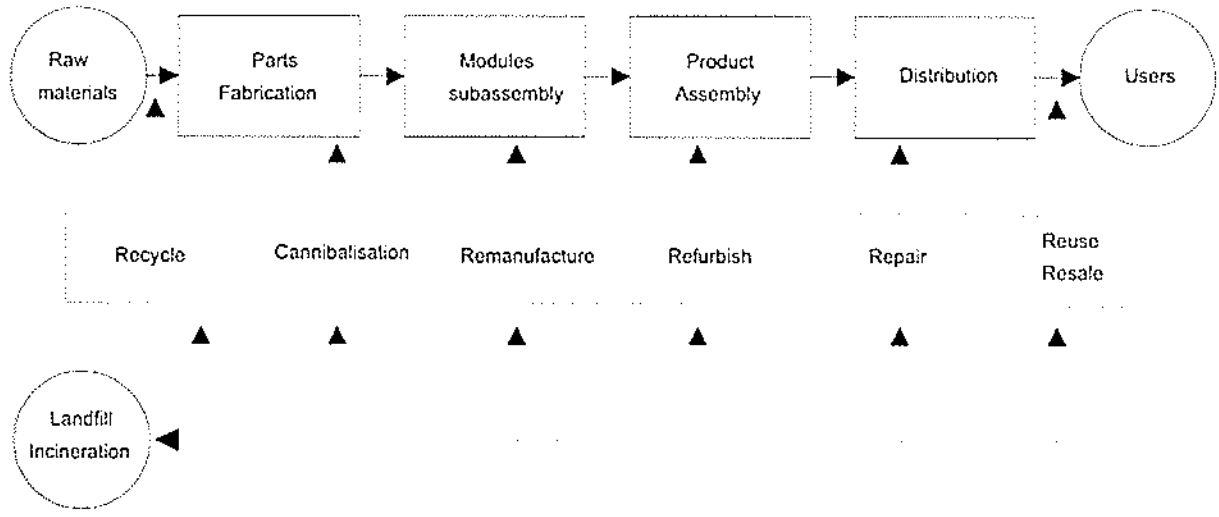


Figure 4. Adaptation from Thierry *et al.*(1995) made by Rudi *et al.* (2000).

A CLOSER LOOK TO REPAIR ACTIVITY

The concept of repair is not new in the same meaning as reverse logistics or remanufacturing concepts may be considered "recent". The repairing activity has traditionally played a role and has very frequently been assigned to the customer service department, where consumers with, warranted or not but, defective products often would return them to their suppliers (Meade & Sarkis 2002). However, the new drivers in the market, already discussed, have led the companies to contemplate the reverse logistic and repair services as

an option to additionally comply with legislation and maintain full control on the product in a tough competitive environment (Blumberg 1999).

Repair is included within the post-transaction heading of the customer service categorization referred by Christopher (1998). The aim of repairing a product is to return it to useable condition, although the fact of giving it back a "working order" status does not mean giving it back the quality it had when it was new (Thierry *et al.* 1995). Repair of specific failures is instead one of the possibilities of extending product life (Shu & Flowers 1995). Repair, then, should not be mixed up with remanufacturing since products in remanufacturing scenario are totally disassembled and all parts are returned to like-new condition (Guide 2000). Unlike remanufacturing or recycling, the level of product dismantling that is required for carrying out the repair tasks is usually minimized to the broken/faulty part that needs to be replaced. The remaining parts of the product are as far as possible kept untouched (although, in last instance, the final degree of disassembly will strongly depend on the type of the failure detected). In general terms, if recovery may be executed at four levels (product, module, part and material), repair implies recovery at the product level (Thierry *et al.* 1995).

When talking about the activity of repairing, different actors may be involved. When the term repair is used, one usually tends to think of a business-to-consumer scenario. In this scenario, customer may send back products, during or beyond of warranty period, to be repaired, whenever the performance of the product is not within the tolerances promised or expected by the standard or when a defect or breakdown prevent from the normal use. However, final consumer is not always the one who return back products to previous participants in the forward logistics chain. A retailer or a distributor may also face the need of having some products repaired if these do not satisfy the proper conditions to be sold in the market.

This activity is doubtless the one among the spectrum of recovery options that has a more direct effect on customer perception of the service quality of the company. The level of

reverse logistics implementation may therefore play a seminal role in improving that perception. Whether a product is recycled or remanufactured, disposed of in landfills or burnt up for energy, the customer loses track of it because, in those cases, he is not expecting to having it back, at least not the very same unit. It is not a matter of having to wait. The customer has got rid of the product and no further worries remain for her, whereas as far as repairable items are concerned, the customer will expect to have another item (with the same characteristics, which will replace immediately the repairable one), or to have the product repaired and in condition of "as new". The speed in taking the (replace or repair) decision and the time in which this decision is translated into action are two key variables that define the perceived service offered by the company to its customers. The urgency of returning the product to normal operation is bigger in maintenance/repairing than in other activities such as remanufacturing (Shu & Flowers 1995)-. That is why Dowlatshahi (2000) considers the activity of repair as one of the aspects, within the strategic factors in reverse logistics systems where to capitalize in customer service. Furthermore, Hillegersberg *et al.* (2001) points out the trend of growing perception of physical products as part of service package, in which repair and maintenance contracts may be included among others. Companies, deeply aware of the long-term benefits generated by the loyalty of their clients to their brands, have shifted from a simple customer-service-oriented policy to a complete customer satisfaction strategy (Mason, 2002).

As in other recovery options, a cost analysis should be accomplished in order to know when:

1. Excessive repair requirements make the repairing not an option (and the disposal or recycling should be chosen instead), or
2. If the product is valuable enough, the refurbishing option is preferred because the resale price will further offset the cost incurred, or
3. The repairing option is the most advisable one.

"Repairables inventory" systems are considerably more complicated than traditional "consumables inventory" systems (Guide & Srivastava 1997). These kinds of systems have drawn the attention of some authors. Panisset (1988) applies MRP II to a workshop operated by the West Australian Government Railway. Moffat (1992) focuses on the repair and maintenance systems within the Royal Air Force. Furthermore, Richter (1996) study the EOQ model when both newly made products and repaired used products are utilized to meet stationary market demand, and Diaz & Fu (1997) analyze the repairable inventory model for the Caracas subway system. Guide & Srivastava (1997) make a review of the literature, examining various models. Blumberg (1999), by means of a survey, analyses the size and dimension of reverse logistics and repair service market and identify its future trends. Finally, Donker and Van der Ploeg (2001) study the case of repairable service part of telephone exchanges. Despite the papers listed here, the number of publications regarding the issue of repairing is remarkably smaller than when other return reasons or options are taken into account despite the requirements ISO 9001 systems and other criteria put on management of customer-owned products since the 1980s. De Brito *et al.* (2002) attribute this fact to the difference mainly in the contractual side. However, this may be only a temporary situation. Progressive environmental demands and the ever more demanding legislation are producing a remarkable change in attitudes. What before was designed to be discarded and disposable, is now looked at as a potential, modular products are substituting more compactly-designed ones, repairing an used item is less harmful from an environmental viewpoint than producing a new unit, etc.

The inventory of repairable items, as it usually happens with any other kind of inventory, implies, if not managed carefully, the investment of handsome amount of money. Repair service providers (OEM or others) face the problem of uncertainty, already mentioned. Good customer service demands either a deployment of a very effective and efficient logistics system so as to guarantee the ordering and delivering in time of the required parts, or a good assortment of spare parts on their facility shelves, waiting for the presence of the customer in their premises to know exactly what precise spare part is needed. The latter condition may lead to excess stocks of parts and components to guarantee the service, the

more so if the final product traded is a complex one, in the sense of being assembled from a big number of parts.

Of course, the nature of products may reduce slightly this uncertainty as a suitable design may facilitate the forecast of the defective return flows. Thierry *et al.* (1995) conclude that "electronic components tend to follow a random failure pattern over time, whereas mechanical components often tend to wear out with age".

The uncertainty makes the decision making process regarding the number, size and capacity of the repair centre locations difficult as well. These facilities, equipped with specialized personnel, are devoted to handle repairable items in a centralised and quicker manner, avoiding, on the other hand, these return flows to go further backwards in the reverse logistics chain.

On the other hand, repairable items may present different states, such as the "serviceable", "unserviceable", or "in the process of repairing" stage (Tan & Kumar 2003). This multitude increases the level of holding costs with more likelihood than if only one category would exist. Furthermore, the need for an adequate information system that facilitates numbering, tagging and tracking both items that belong to those three categories and the parts waiting for others to be repaired in order to be again reassembled, poses an additional burden to the system (Guide *et al.* 2000).

Finally, added-value recovery is a common feature among the repair and remanufacturing activities when relatively high value assembled products are concerned. Repair is usually chosen when high costs are involved, long-life goods where it is cheaper to repair the item than to discard it and buy a new one instead. (Guide & Srivastava 1997). Under these circumstances, the repairing is usually taken care of by the OEM –or their authorized representatives- since deep knowledge about the product is required (Fleischmann *et al.* 2000).

2.3. SOME UNIQUE CHARACTERISTICS THAT STEM FROM THE BACKWARDS FLOW

Reverse logistics systems cannot be considered as the reverse version of forward logistics system (Fleischmann *et al.* 1997) even if some authors (Zikmund & Stanton 1971) have suggested so in the past. Even though an common environment obviously connects both the forward and reverse logistics disciplines (both are affected by strategic issues such as strategic costs, overall quality, customer service or by operational issues such as, supply, transportation, warehousing, etc.) and some techniques may be to a certain extent, translated from one to another with reasonably little effort in adaptation, the translation is far from being total and straightforward. Several specific features of recovery environments make it difficult to adopt traditional tools and techniques from conventional manufacturing systems. Guide, Srivastava & Spencer (1997) point out, for instance, the difficulties in applying traditional methods of manufacturing planning and control.

The following discussion of these factors is based on the study of Guide *et al.* (1997).

2.3.1. UNCERTAINTY

Uncertainty is related to when (time), how many (quantity), what kind (diversity) and in which condition returns will take place (see also Koster, Vendel & de Brito 2001). Unlike the traditional supply chain where supply is organized according to the manufacturing process needs, supply in reverse context is in most of the cases random. The consequent mismatch between supply and demand may easily result in excess in inventory of some unwanted certain units (Veerakamolmal & Gupta 2000) coupled with shortages of some required units. Demand from markets is nearly always subject to uncertainty, so this statement applies to both new products and reprocessed ones. The difference lies in that the company is not able to refuse the excess of a certain component in inventory because this excess is irremediably united to the possibility of meeting another component demand, both

components obtained simultaneously from the disassembly of a returned product. Finally, the uncertainty about the condition of the returned product (known only after a proper disassembly, inspection and testing) makes it extremely difficult to organize the operational tasks to be performed, as the appropriate recovery option cannot be elucidated beforehand.

One useful tool for reducing, to a certain extent, the level of uncertainty is the Life Cycle Analysis[19] (LCA). The role of this concept has become prominent over the last two decades in environmental decision-making. According to Fava (1991: 19.):

LCA *is an objective process used to evaluate the environmental burdens associated with a product, process or activity. This is accomplished by identifying and quantifying energy and material usage and environmental releases. The data are then used to assess the impact of those energy and material releases on the environment, and to evaluate and implement opportunities to achieve environmental improvements. The LCA includes the entire lifecycle of the product, process or activity, encompassing: extracting and processing of raw materials, manufacturing, transportation and distribution, use/re-use/maintenance, recycling and final disposal.*

The life cycle of a product (and its separate parts an components) is often long and very complicated to define. It covers all the areas from the extraction of natural resources, through their design, manufacture, assembly, marketing, distribution, sale and use to their eventual disposal as waste. At the same time, it also involves many different actors such as designers, industry, marketing people, retailers and consumers. Additionally, any life cycle interrelates with many other life cycles (Gray, Bebbington & Walters 1993); therefore, an LCA analysis needs a previous demarcation of its boundaries. Finally, LCA is affected by subjectivity in the analysis as it is usually conditioned by the goals of the organization

[19] LCA also stands for Life Cycle Assessment. However quite other many names can be found in literature to refer to it or with similar meanings: cradle to grave analysis/assessment, eco-balance assessment, resource analysis, environmental impact assessment, etc.

conducting it[20]. One example of its application in repairing environment can be found in Fortuin & Martin (1999: 951).

2.3.2. LAYOUT OF THE REVERSE LOGISTICS NETWORK

An immediate consequence of the previous feature is the difficulty to decide on the reverse logistics network. The layout of this network should be such that returns transport and warehousing operations will be operated in an efficient manner and capable of capturing the relationships among the various parties involved (Gungor & Gupta 1999; Philipp 2000). Decisions have to be made regarding whether reverse logistics procedures should be carried out in-house (that is, deploying the company's own infrastructure) or if all these activities should be outsourced to a third party logistics provider.

The decision about which of these two options to adopt belongs to the long-term strategic sphere and therefore, special care should be devoted to it. Two key aspects should be taken into consideration regarding this decision (Dunn 1999):

- To what extent the reverse logistics activities are important for the company from a strategic standpoint, i.e. which option guarantees a strategic competitive advantage?
- Which of the two options best contributes to the company profitability and provides a cost-effective customer service?

---

[20] One example is the disposable diapers -related debate between Procter & Gamble and the Landbank Consultancy, an independent organization which conducted, at it's own expense, a life-cycle analysis. The Landbank Consultancy used P&G's own data to arrive at startling different conclusions. Disposable diapers:

1. Produce 60 times more energy
2. Use three times more energy
3. Consume between 10 and 20 times more raw materials
4. Consume two times as much water, even when cotton growing is factored in.

(See more details in http://www.dy-dee.com)

Another scenario to be studied is the convenience of integrating both of the logistics chains (forward and reverse) or keeping them separate; in the prior case, coordination of both processes is critical to avoid capacity problems and excess of stocks (Inderfuth & Teunter 2001). Besides, the network should be flexible enough to give adequate answer to the many possible exceptions, which may come up. Questions on how to perform the collection from usually a great number of small volume supply points, where to locate the inspection centre, how to organize subsequent operations scheduling depending on the product destination chosen according to the condition of the return, or the internal routing and handling, may arise among others.

2.3.3. AMOUNT AND SCOPE OF THE ACTIVITIES PERFORMED

Intakes in the recovery of products involve a greater number of logistics activities to be performed than for the traditional logistics. Some of these activities are:

- Collection, which includes all those operations necessary to pick up used products from a certain point in the chain so that they can be shipped further to another point in the chain (Fleischman *et al.* 2000: 657; Fleischman 2000: 44). In collection, not always the consumer is the starting point. If this however is the case, different schemes may be found ranging from bring schemes to kerbside collection, from co-collection to segregated schemes[21] (Jahre 1995).

- Transportation is one of the largest contributors to the total reverse logistics costs (30%-50% according to Kopicki, Berg, Legg, Dasappa & Maggioni 1993). Problems derived from organizing transportation of returns mainly affect to those companies that have

[21] Although the author of this thesis has also accomplished some studies in this field (Fernández 2003c; Fernández, García, Puente & Mitre 2003), because the focus of this thesis was Reverse Logistics practices in manufacturing companies, the results from these previous pieces of work were not included in the present document.

adopted in-house solution[22]. The complexity stems from different sources: first, the variety of products to be handled of (including their packaging materials); secondly, the fact that the product may be sent back without the protective, standard size package with which was sent forward. Additional questions to take into consideration are whether to combine product returns and forward flows or not, simultaneous or separate delivery and pick up, the trade-off between the optimal exploitation of the trucks and carriers and the increase of complexity of the operations, and so on (Koster *et al.* 2001).

- Storage: reverse logistics poses one of the 21st century warehousing challenges mentioned by Brockmann (1999:38). He states: "As the amount of reversed flow goods entering the warehouse increases, the successful organization must develop cost-efficient and effective methods to control the increased labour associated with freight, receiving, claim processing, credit notification and disposal".

- Inspection, which is a set of operations whose aim is to assess the condition of the returned product. The subsequent activity will be then sorting.

- Sorting: According to the results of the inspection, the products will be grouped in different categories mainly defined by their next recovery destination.

- Disassembly. This is a distinct characteristic of the recovery environments. Most of the recovery activities require a certain degree of disassembly (Johnson & Wang 1995). After the products have gone through the previous operations, the disassembly is the activity that opens the possibility for other recovery activities to take place. Outsourcing this activity from 3rd party logistics operators usually poses a big challenge given the lack of concrete specifications provided by the OEM about how to do it. The lack of concern about designing for disassembly in the stages previous to the launch to the market make this task one of the most critical one of the recovery process. The causes

[22] Several 3PL providers (third-party logistics providers) were enquired about this subject. They assessed that their business key was having flows to carry and not paying much attention to the kind of flows they carry.

for this are the different levels of disassembly that may be required depending on what is wanted or what is the condition, the high qualification needed in most cases to execute this activity without damaging the architecture of the product, etc. The reason behind the criticality of this issue is that in most of the cases, only after fulfilling the disassembly of a product, the decision about the next destination for it can be made. It is for instance possible that the failure which provoked the product to be sent back for being repaired, is so serious (whether technically or economically) that repairing is not longer considered and remanufacturing or recycling are deemed instead.

Several issues are posed when facing the disassembly decision. First of all, the location where the disassembly should take place is important. The decision of carrying out the disassembly in the same facility to which the materials were first brought after collection, in a central facility, at the original manufacturing site or in the third-party provider's premises has direct effect on transportation costs, storage, sorting, etc. in short, on total reverse logistics costs. Closely linked with this, the second issue is the decision to be made about collaborating with other firms, even with competitors, in order to obtain economies for disassembly. Linked with this question lies how to perform the disassembly, either at a single workstation (disassembly cell) or on a disassembly line (Wiendhal, Lorenz & Bürkner 1998).

A third important question refers to the knowledge about if the profitability of the operation. The operation of disassembly has traditionally been a labour-intensive task. According to Johnson & Wang (1995), the answer is obtained after pondering the importance of the following three variables: the reclamation value, the savings of non-disposal and the disassembly costs. When the sum of the first two is superior to the dismantling costs, then the disassembly should be performed.

Additional questions focus on what to disassemble, what is the economical optimal level of the disassembly planning process for material recovery or what are the most efficient disassembly sequencing plans.

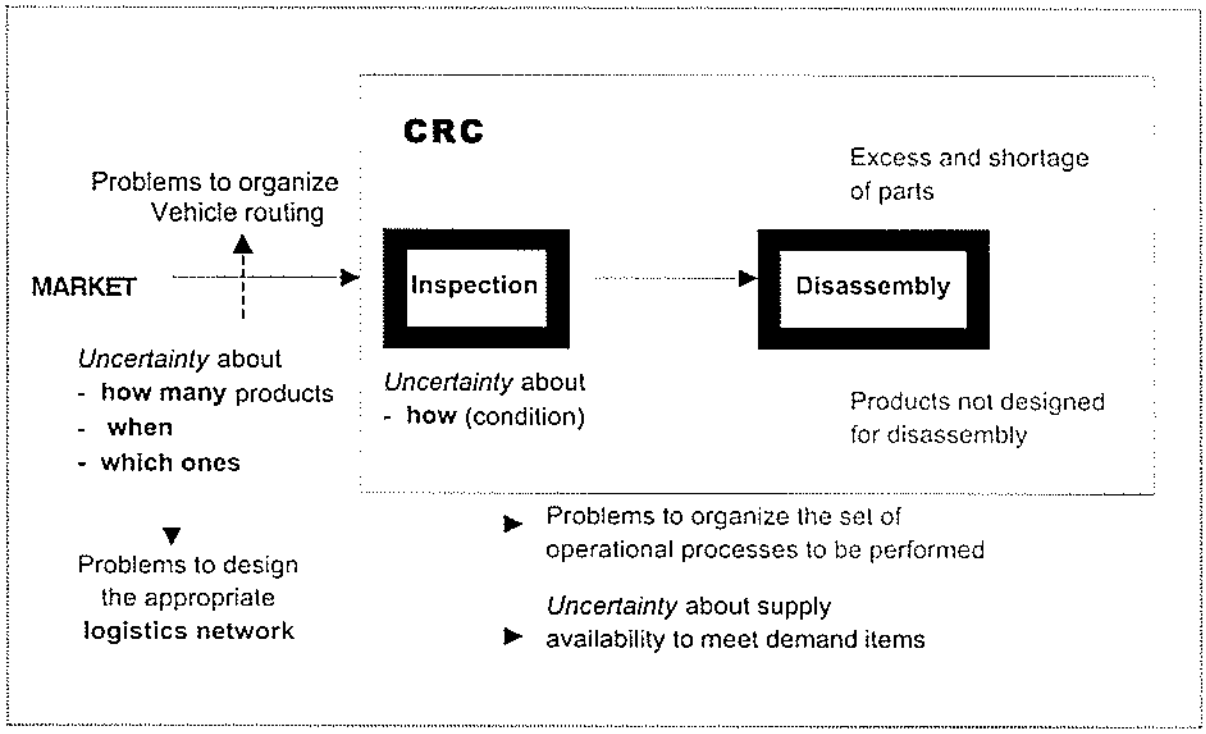


Figure 5. Unique challenges posed by returned products.

2.3.4. VOLUMES OF THE FLOWS

Leaving aside the end of life items, which in the most optimistic scenario will imply fairly the same amount of units within the forward and the backward chain, the remaining types of backwards items represent logically a tiny portion of the ones shipped forward. Manufacturing processes are designing to produce high quality units; otherwise the company could any longer compete in the market. Defaults, failures, etc. may happen because materials, equipment and labour are not infallible resources. However, companies try to minimise these undesirable margins of error or at least, to keep them within certain acceptable tolerances. Therefore, when talking about reverse logistics volumes, it should be kept in mind that they never reach the levels of traditional logistics.

Table 4. Differences between traditional and recoverable environment (Guide *et al.* 2000: 131).

FACTORS	RECOVERABLE MANUFACTURING ENVIRONMENT	TRADITIONAL MANUFACTURING ENVIRONMENT
Environmental focus	Seeks to prevent postproduction waste	Environmentally conscious design and manufacturing, focus on pre-production
Logistics	Forward and reverse flows	Only forward flow
	Uncertainty in timing and quantity of returns	No returns
	Supply-driven flows	Demand-driven flows
Production planning and control	Need to balance demands with returns	No such need
	Material recovery uncertainty	Certainty in planned materials
	Stochastic routings and processing times	Fixed routings and more stable processing times
	Manufacturing system has three major components: disassembly, remanufacturing, and reassembly	Manufacturing system has two major components: fabrication and assembly
Forecasting	Forecast both core availability and end-product demand	Forecast only end products
	Must forecast part requirements because material recovery rates are uncertain	No parts forecasting needed
Purchasing	Highly uncertain material requirements due to variable recovery rates	Material requirements deterministic
	Cores and parts and components, replacement parts, components	Raw materials, new parts, and components
Inventory control and management	Types: cores, remanufactured parts, new parts, new and remanufactured substitute parts, original equipment manufacturer parts	Types: raw materials, work-in-process, finished goods
	Must track and provide accounting for all part types	Must track and provide accounting for work-in-process and finished goods

Another question is if all the items susceptible of entering the backwards chain actually do. It seems that the answer is negative. The effect of environmental legislation is to avoid the deviation of these kinds of products but still volumes could be notably raised. Some of the factors that affect the volumes of reverse flows are the contract clauses between the manufacturer and the customer, the follow-up of life cycle stage of the products, the environmental legislation, the cultural factors that influence environmental awareness (Hofstede 1994), and technological change rate. (Ayres *et al.* 1997: 558-9).

2.4. SYNTHESIS OF THE CHAPTER

Although some authors such as Ackerman (1997) claim that returns have always taken place and, consequently, their management should not pose any new complexity, some other authors acknowledge that the reverse logistics special characteristics make its planning and organization not only different but also more intricate than the traditional logistics.

This chapter has illustrated the main features of this emerging discipline. First, a proposal of a concept was made, based on the lack of a unanimous vision of the field and its main concepts. Then, the main forces that may justify the interest for companies in the adoption of reverse logistics practices were listed and explained. Their importance varies, but perhaps the three first drivers in the list are the ones with more influence. This part of the chapter constitutes the concept-analytical part of this work and is a contribution in itself.

The description of the state of conceptual and practical state of the research field was followed by a discussion of the types of physical items that most often take part in the reverse flows, in order to build the empirical approach of this work. Next, the recovery options connected to reverse logistics activities were briefly mentioned, making a distinction between those that extend product life and those that extend the material life. From a sustainable standpoint the prior are the more desirable. However, when for one reason or another, these alternatives are not technically, technologically or economically viable, the latter will be always preferable to the disposition of the items. Reverse logistics plays a critical role in accomplishing these recovery options, giving operational support from the point of origin to the point of destination. The option of repair was analysed in more detail as manufacturing companies that practice it were chosen as the focus of this thesis.

3. EMPIRICAL RESEARCH

This chapter is structured in four parts. The first one (Chapter 3.1.) briefly revises some theoretical aspects of the selection of research methods used in the empirical part of this thesis and gives a justification for their utilization. Two of these research methods (Focus Group and Case Study) belong to the category of the qualitative research, which is discussed in Section 3.1.1., whereas the third one (Analytic Hierarchy Process) is considered in some texts as a quantitative research technique (see Section 3.1.2.).

In the remaining three parts (Chapters 3.2, 3.3 and 3.4), the empirical applications of previous techniques in this thesis and its research questions are presented. Each part starts with an introduction to the specific topic analysed, then continues with corresponding review of literature, the particularities encountered in the design and application of the research technique, and finally ends the chapter with the results obtained, discussion and concluding remarks.

3.1. METHODOLOGY

3.1.1. QUALITATIVE RESEARCH: SOME NOTES

Although research methods can be categorized according to different criteria, one of the most common distinctions is between qualitative and quantitative research methods.

- Quantitative research methods, originally based in the natural sciences to study natural phenomena, are nowadays also utilized in social sciences. They include survey methods, laboratory experiments, formal methods (e.g. econometrics) and numerical methods such as mathematical modelling.

- Qualitative research methods focus on social and cultural phenomena that cannot be quantified. Examples of qualitative approaches are action research, case study research and ethnography. Qualitative research involves the use of qualitative data, such as interviews[23], documents[24], and participant observation data, among others (see Patton 1986, for a broader description), to understand and explain social phenomena. Some of these are also possible to quantify, but this changes the setting. For example, Kaplan & Maxwell (1993) argue that the goal of understanding a phenomenon from the point of view of the participants and its particular social and institutional context is largely lost when textual data are quantified.

  Since qualitative research methods are those mainly used in this thesis, some additional features are provided (Sykes 1991):

  1. Qualitative research is usually conducted in small samples;
  2. Samples are non-randomly selected. Rationale lying behind is that the goal is not to cover the most of individuals, characteristics, etc. as it could be in quantitative research;
  3. Neither are samples haphazardly selected. Systematic procedures are followed.
  4. Qualitative research is data-driven, that is, conclusions stem directly from the data.

3.1.1.1. FOCUS GROUP

The focus group method has been defined (Krueger 2000) as a carefully planned discussion designed to obtain perceptions in a defined area of interest in a permissive, non-threatening environment. This technique is therefore designed to collect information about an issue from a small group of selected people through group discussion. Although the origins of

[23] Interviews are an example of what is called "primary resources"; generally speaking, primary sources are those data which are unpublished and which the researcher has gathered from the people or organization directly

[24] Secondary sources refers to any materials (books, articles etc.) which have been previously published.

this methodology are claimed to be in the evaluation of audience response to radio programs in 1941 made by the social scientists Robert Merton (Stewart & Shamdasani 1990), today's applications are found in a broad range of fields.

Focus group techniques have the potential to provide rich information and focus respondents' thinking and reflection on salient aspects under investigation. In contrast to Delphi groups, where consensus is the desired outcome, the aim of focus groups is to get a range of views on an issue. When focus group is compared to a group interview, it is found that the first emphasises dynamic group interaction. A group interview in qualitative research can mean a set of individual interviews conducted in a group setting. A focus group however, encourages a conversational approach, the researcher playing essentially a role of moderator. Thus, many views are acquired, which is especially suitable to structuring not so well known issues and topics.

Merton, Fiske, & Kendall (1990: 137) suggest that "the size of the group should manifestly be governed by two considerations: it should not be so large as to be unwieldy or to preclude adequate participation by most members nor should it be so small that it fails to provide substantially greater coverage than that of an interview with one individual".

In other words, group size needs to be small enough to ensure that everyone can participate but large enough to provide a range of perspectives. Regarding the number of questions to be posed Krueger (2000) suggests less than ten questions (often around five or six); coincidently, Stewart & Shamdasani (1990) propose "fewer than a dozen questions". Finally, questions should be unstructured, open-ended questions so the respondents could answer them from a variety of dimensions and viewpoints.

For a successful development of the focus group, Lederman (1989) considered five conditions, which the method should be based on (see also Byers & Wilcox 1991):

a. People are a valuable source of information

b. People can report on and about themselves, and they are articulate enough to verbalize their thoughts, feelings and behaviours
c. The facilitator who "focuses" the interview can help people retrieve forgotten information
d. The dynamics in the group can be used to generate genuine information, rather than the group think phenomenon
e. Hearing a group is better than interviewing an individual.

10 guidelines are proposed by Axelrod (1975) in order to ensure successful performance and concrete results for a focus group (see also Angell & Klassen 1999; Byers & Wilcox 1991):

i. A clearly understood objective
ii. Homogeneity within the group
iii. Effective recruiting of participants
iv. A relaxed atmosphere
v. Active listening
vi. A well prepared moderator
vii. Free-flowing dialogue
viii. Restrained group influence
ix. Skilled analysis
x. Competent researchers.

As a concluding remark, some pros and cons of this technique are highlighted. The major advantage of conducting focus groups could be considered its ability to obtain in-depth and detailed information through group synergy[25].

[25] Group synergy occurs when one participant says something that triggers an idea from another participant.

On the other hand, the disadvantages are threefold:

1. Because the participants are not chosen randomly, outcomes and opinions can be biased in a way that restricts the value of the findings;
2. The sample size is usually kept small (between 8 and 10 members) which also leads to possible restriction in the scope of opinions;
3. Organising the groups may be expensive.

Although Focus groups can be used at any point in a research program, this technique was planned to be used in this thesis for generating research questions that could then be submitted to further research and testing by means of other approaches. Furthermore, due to the relative immaturity of the research area, this approach was also useful for screening the relative importance of problems with implementing reverse logistics procedures in companies. It was, therefore, the first empirical research technique used in this work.

3.1.1.2. CASE STUDY

The case study was defined by Yin, in 1984, briefly as a possible research strategy but in 1989, in more detail as an objective, in-depth examination of a contemporary phenomenon within some real-life context about which the investigator has little control over events. Given the nature of the reverse logistics topic and the, so far, small amount of research on it, the present author has in this thesis adopted the case methodology in an attempt to study this unfamiliar situation (Voss, Tsikriktsis & Frhlich 2002).

Yin (1989) also mentions the case study to be an appropriate tool when "why" and "how" questions are to be posed to the phenomenon[26], "why" looking for understanding and "how" for explanation (Meredith 1998).

[26] The survey or the archival analysis were at this stage of the investigation dismissed since our interest is not focus on "how many", "who" or "where", questions more oriented to describe frequencies or incidence of a phenomenon. History strategy was also discarded, as the focus is not on a "dead" past; still alive managers

Case studies can either be explanatory, descriptive or exploratory, each of these types having different orientations. According to Yin (1998: 236), exploratory case studies are the preferred orientation "when the available literature or existing knowledge base is poor, offering no clues for conceptual frameworks or notably propositions". This seems to adequately fit to reverse logistics arena.

Regarding the number of cases the study should embrace, there is no unanimous agreement between academics (Eisenhardt 1991; Dyers & Wilkins 1991). A case study may be about single or multiple cases. It is possible to generalise from single cases (in some analytic way) but multiple-case studies can strengthen or broaden such generalisations (similar to the advantages of multiple experiments). From reviewing the literature, examples of both, single and multiple, case studies can be found (Harris & Sutton 1986; Leonard-Barton 1988, Drumwright 1994; Handfield, Walton, Seegers & Melnyk 1997). Although Dyer & Wilkins (1991) believe that two cases at the most might already be enough, Eisenhardt (1989) however recommends a number between four and ten cases as appropriate. The choice of fewer cases could jeopardize the extraction of a grounded theory from them, while a bigger number could make complex the processing of the information gathered. Only when iterative triangulation is to be applied, the number of cases would be increased to 20-30, according to Lewis view (1998).

Six case studies were analysed in this thesis. The cases were selected along the following criteria.

- Firstly, cases were chosen so that theoretical replication was achieved, in other words, contradicting results could be found but for predictable reasons. The purpose was to be able to better delineate contrasting features in reverse logistics practices.

---

will be interviewed in our study as one of the possible sources of information. Experiments did not fit in our scheme as we were not interested in manipulating behaviour directly and systematically.

- Secondly, Goffin (1999) stated "the need for a wider investigation of customer support (within which the repairing activities are included), covering sectors other than computing and electronics". It was of interest to know what the reverse logistics patterns were, also in sectors different to those already mentioned by Goffin. According to this idea, the sample was designed so that the presence of companies operating in some of the key sectors of Finnish industry was ensured. However, the sample was enriched with the participation of other firms operating in different markets.

- Finally, a feature present in most of the companies selected was their international orientation and their leading position in the worldwide markets. Even if the percentage of returns from total sales in these businesses usually is small (except for e-business markets where this percentage considerably increases), the big invoicing volume of these leading companies seemed, at least a priori, to guarantee a certain critical returns mass. This, together with the complexity of the worldwide market, would mean that in these companies implementation of reverse logistics processes would be justified. The size of the company was understood in terms of geographical scope, total sales and workforce.

From the five methodological options for the construct of a case study mentioned by Barnes (2001) – ethnography, interviews, strategy charting, questionnaires and documentation- interviews and documentation were the ones used in this work. Therefore, after having selected the companies, the most suitable personnel were sought for the interviews (given the nature of the theme, usually logistics managers or after sales managers). In most of the cases, the main points to be addressed were sent in advance to the interviewees via electronic mail, while making clear that the questions stood more as open guide for the meeting ("focused, open-ended interview") than an structured plan to be tightly adhered to ("structured interview"). Apart from the information gathered during the interviews, other sources of data, such as annual reports, brochures, press news, internal studies, etc. were consulted whenever possible. The bulk of information however was obtained from the interviews.

Before carrying out any case study, Yin (1989) suggests answering to the following points:

1) What is the topic or area to be investigated?
2) What is the aim of the research?
3) Which are the criteria to judge the success of the investigation?

The previous work accomplished in the thesis up to this point (review of literature, focus group) gave the necessary support to respond to the first two questions. With respect to the third, four tests are relevant and were used as explained in the following:

- Construct validity, which refers to the operational measures taken for the topic being studied. Construct validity was sought by a) utilizing multiple sources of evidence in the data collection phase, b) establishing chain of evidence by transcribing interviews in real time and by entering evidence sources into customised object-oriented database and c) having the cases studies reviewed by the respondents and by presenting them in conferences for an audience of fellow researchers.

- Internal validity, which relates to establish causal relationships, i.e. how to demonstrate that some outcome was caused by independent variables (Ellram 1996). In the data analysis phase, a pattern matching technique (Campbell 1975) was used to identify common features across the respondents' responses to questions, with which to do some clustering and some explanation building across the cases.

- External validity, which implies the definition of the domain to which the study's findings can be generalized. This was attained through replication in the research design phase and by testing the propositions further by applying the AHP.

- Reliability, which aims to demonstrate that the procedures used can be repeated, with the same results. Although the use of a tape recorder was known to improve the

reliability of interview data (McCutcheon & Meredith 1993: 246), none of the respondents were especially willing to be recorded; consequently, this option was dismissed. Instead, the same data collection procedure was followed for each case and interview transcripts and other pieces of information were directly entered into the database. There has also been an attempt to "richly" report the data collection methods and the responses behind the proposed results (Sykes 1990:8-9).

3.1.2. QUANTITATIVE RESEARCH: ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP) is a multi-attribute modelling methodology first introduced by Saaty (1980) to establish the weight factors between alternatives in decision-making. It has been successfully applied in industry, government and research establishments ever since (see Saaty 1990). A comparison of five methods for determining weights in additive utility models by Schoemaker & Waid (1982) found AHP to be the best technique.

AHP is one of the most adequate tools to transform the impressions drawn from the case studies into arguments upon which future decisions can be made. This is possible because the subjective impressions can be quantified and processed in an objective fashion. Although AHP has been criticised for inducing a rank order when none exists (Schenkerman 1997), or for modifying the ranking of a set of alternatives when a so-called irrelevant alternative is introduced (Dyer 1990), AHP advantages seems to far offset its weaknesses.

AHP consists of a series of steps. The first of these is structuring the problem information, usually in a decision tree form, so that a hierarchy is obtained. Secondly, the method establishes priorities among the elements of the hierarchy from the judgements from a group of expert members, by means of a tailor-made questionnaire. Then, aggregating the individual priorities yields a set of overall priorities. Consistency of these judgments is checked.

Judgements in AHP technique are the result of comparing pairs of individual elements. Respondents will be asked to assess which of the two elements in each pair is more important regarding a specific criterion, and how much more important it appears to be. Values for measuring this importance will range from 1 to 9 to both directions, according to the scale shown in Table 4 and Figure 7.

The responses to the questionnaire were translated to matrix format (see Figure 6), which facilitates the posterior estimation of the priorities for each respondent. Comparisons are always made by evaluating the element in the left-hand column of the matrix in its relation to the element in the top row. The matrix is triangular in the sense that the reciprocal value is automatically obtained.

Table 5. Value scale used in AHP.

INTENSITY OF IMPORTANCE	DEFINITION	EXPLANATION
1	Equal importance	Both elements contribute equally to the criterion
3	Moderate importance	Experience and judgement slightly favour one element over another
5	Essential or strong importance	Strongly favour
7	Very strong importance	Strongly favour and its dominance is demonstrated in practice
9	Extreme importance	Evidence favouring one element over another is the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	
Reciprocals	When element *i* compared to *j* is assigned one of the above numbers, element *j* compared to *i* will get the reciprocal	

CRITERION	Element 1	Element 2	.....	Element n
Element 1	1		.....	
Element 2		1	.....	
.....	.....	.....	1	.....
Element n			.....	1

Figure 6. Matrix format in AHP.

The so-called "priority vector" of each respondent gives his priorities among the n elements in the matrix. This vector is calculated as the eigenvector for the largest eigenvalue of the matrix. Then, the overall consistency of his judgments is measured by means of a consistency ratio (CR). CR can go from zero (true consistency of the input) to a very large positive number. CR threshold values depend on matrix' size (Saaty 1994) and the criteria is shown in table:

Table 6. Consistency Ratio threshold values.

MATRIX DIMENSION	CR TRESHOLD VALUES
3x3 matrix	0,05
4x4 matrix	0,08
Larger matrices	0,1

Only judgements found to be consistent were entitled as candidates to be aggregated. The method utilized was the so-called "aggregation of individual priorities", AIP[27] (Forman & Peniwati 1998). The aim of the aggregation process was to obtain overall priorities. Although in the AIP context both the arithmetic and the geometric means are meaningful, Saaty (1989) suggests using the latter. In such a case, and having n individuals, the geometric mean will be obtained as the n^{th} root of the product of the n individual priorities.

[27] Since respondents to the questionnaire have no connection at all among them, respondents were treated as independent entities and therefore overall priorities resulted from aggregating individual priorities instead individual judgements.

Given that the evaluation procedure may result to be highly repetitive and lengthy and may therefore discourage the willingness of mostly busy respondents to collaborate with the data collection, the emphasis was put to gather 4 blocks of information, each of which corresponded to one critical criterion found. Within each of these blocks, respondents were invited to compare pairs of alternatives with influence on those criteria. The format first chosen to gather their responses was a questionnaire (see Figure 7). The number of comparisons differed in each block; e.g. the first block (a 9 dimension matrix) contained 36 pairs whereas the last block (from a 3 dimension matrix) comprised only 3. The remaining cases comprised 4 and 6 dimension matrices. The complexity stemmed from the high numbers of comparisons, above all in the first block, made us fear for the consistency of the answers; this is because permanently keeping track of the previous answers is more difficult when the amount of comparisons increases. Actually, literature warns not to exceed matrix dimensions of 5 (Bodin & Gass 2003), as the human capacity to tackle with more issues seems to be subject to some limitations (Miller 1956).

B) Please, select which is the most important **ACTOR** in each of the following pairs when it comes to **EXTERNAL PRESSURES TO BE INVOLVED IN REVERSE LOGISTICS PRACTICES**

Government	9 7 5 3 1 3 5 7 9	Customers
Government	9 7 5 3 1 3 5 7 9	Suppliers
Government	9 7 5 3 1 3 5 7 9	Competitors
Customers	9 7 5 3 1 3 5 7 9	Suppliers
Customers	9 7 5 3 1 3 5 7 9	Competitors
Suppliers	9 7 5 3 1 3 5 7 9	Competitors

Figure 7. An example of the type of question utilized in the AHP analysis.

Respondents were asked to select one of the two options in each pair and to assign a value according to the importance given. This format was used as a pre-test in a company; oral explanation about how to fill the questionnaire was found to be feasible. After collecting

the information and processing it in the computer by using three different methodologies (the one proposed by Saaty in his book, the Expert Choice program and Matlab software), the level of inconsistency was found to be so high that it invalidated the information. The inconsistency results were 0,3 in first question (9x9 matrix), 0,11 in second question (4x4 matrix), 0,16 in the third (6x6 matrix) and 0,03 in the last one (3x3 matrix).

While analysing these test, a doubt about the adequacy of the questionnaire arose. The alternative was to resort to the matrix format proposed by Saaty. Although the scale value to be used still holds, the way it is used is not exactly the same, therefore a file containing basic explanations on how to proceed was provided along with the questionnaire. The question in Figure 7 was then transformed into the matrix in Figure 8, in which only the shaded cells had to be filled by the respondents.

EXTERNAL PRESSURES	*Government*	*Customers*	*Suppliers*	*Competitors*
Government	1			
Customers		1		
Suppliers			1	
Competitors				1

Figure 8. Matrix format for the AHP study.

The number of comparisons to be made was the same, that is (n*[n-1]/2). However, the fact of having the information much more compacted could ease the process of keeping track of the previous judgements; this was thought to increase the consistency. This format was sent to logistics managers of 86 different companies (chosen from the Logistics Association yearbook), via email. Only 3 sent it back. None of them tuned up with an acceptable consistency ratio in the four questions (matrices) posed.

The results led us back to the first questionnaire although to a restructured version of it. Instead of displaying the questions in the same logical order imposed by the rows of the matrix (from left hand side to the right and from the top to the bottom), the questionnaire

was now re-configured in triples: if first question referred to the pair (a, b) and the second question to the pair (a, c), the subsequent question was meant to assure the transitivity, i.e. the pair (b, c) should be asked. Question in Figure 7 was modified as shown in Figure 9.

This new questionnaire was sent to another 86 companies (none of the same as the initially emailed ones) by normal post. The response rate in this case was a bit higher (15%).

B) Please, select which is the most important **ACTOR** in each of the following pairs when it comes to **EXTERNAL PRESSURES TO BE INVOLVED IN REVERSE LOGISTICS PRACTICES**

	◄——— ——►	
Government	9 7 5 3 1 3 5 7 9	Customers
Government	9 7 5 3 1 3 5 7 9	Suppliers
Customers	9 7 5 3 1 3 5 7 9	Suppliers
Customers	9 7 5 3 1 3 5 7 9	Competitors
Suppliers	9 7 5 3 1 3 5 7 9	Competitors
Government	9 7 5 3 1 3 5 7 9	Competitors

Figure 9. Excerpt of modified questionnaire utilized in the final AHP analysis.

Next section is devoted to the empirical research in which previous methodologies were utilized.

3.2. FOCUS GROUP TECHNIQUE APPLICATION

3.2.1. INTRODUCTION

Already in 1995, Mentzer & Kahn put forward that qualitative research did not seem very well accepted in the fields of logistics, operations research and material management. However, in recent years we have witnessed an increasing prominent role (or at least, a

bigger demand of it) of research methods based on field study, in spite of the fact that these methods may, in some circles, still be contemplated with certain degree of suspicion. This is because some weaknesses have been unfairly imputed to them, such as the lack of both scientific rigor and objectivity, along with insufficient precision, perhaps given the small number of samples, nonreplicable efforts, etc. (Goodyear 1990).

However, the growing demand for qualitative research does not respond to any whim but to an imposing reality, which can no longer be ignored. This reality is characterized, as pointed out by Lewis (1998), by the great number of changes which also both management methods and technology go through. On the other hand, these changes are taking place more and more often and at a higher speed. The reaction of the research community with the increasing interest in this kind of methods is nothing but the necessary answer from theoretical world to the ever-changing reality. The working information about this reality was about to be outdated in certain cases. It was urgent to collect new information, in order to update the old to fit the new circumstances, reducing the abyss between the theoretical and the practical world (Ellram 1996). This was all the more the case since in the academic world the prior (theory) is supposed to explain the latter (praxis) and, therefore, both to develop in parallel.

Qualitative research plays an important role in accessing and generating discussions with key decision makers in organizations and with industry experts (Wright 1996). That is the reason why this methodology serves at bringing closer theoreticians with practitioners, helping to create a body of knowledge based on empirical observations.

In line with McCutcheon & Meredith (1993: 239) and Glaser & Strauss (1999), and against some research currents, we agree that empirical field-based research is one of the main means of developing well-grounded theories and that it is a truly scientific research. One fact that backs this perspective is that the validity of field research has been made evident, during a long period of time, by being used both in social field applications (history, economics, etc.) and in other more practice-oriented fields (urban planning, management,

etc.). On the other hand, the fact of being utilized as a valid and accepted research methodology in quite a number of theses, along with the strategy considerations in our actual situation, offer in our view enough guarantees to be considered as a instrument to be used in the present work.

Reverse logistics is a relatively new field. As Zeller & Carmines (1980) stated, when little is known about a particular problem (and this fully applies to reverse logistics), the focus group may be the appropriate research design to provide a basis for formulating research question and hypothesis. Quite many authors have pointed out the need for further research in this emerging field (Pohlen & Farris 1992; Guide *et al.* 1997; Johnson & Wang 1995; Gungor & Gupta 1999; among others). The focus group technique plays an important role in this kind of new investigation fields and that is the reason why it was chosen in this work.

The remaining of this Section 3.2 is structured as follows: Section 3.2.2. is devoted to give an introductory insight about the Focus Group methodology; Section 3.2.3. puts forward how the technique was adapted to the special purposes of the research; in Section 3.2.4. the results obtained from it are explained; finally, some conclusions are drawn in Section 3.2.5.

3.2.2. FOCUS GROUP TECHNIQUE

Marketing arena seems to have been the natural field in which focus groups found most of its applications. Focus groups have appeared either as the topic of a great deal of marketing-practical oriented research articles (e.g. Cox, Higgenbotham & Burton 1976; Welch 1985; Morganosky & Cude 2000), or the topic of a number of publications in journals of marketing nature (Calder 1977; Fern 1982; Goldman 1962; Wells 1974), as a method of gathering qualitative data. However, it has been virtually ignored in areas other than marketing (Byers & Wilcox 1991). Only recently have researchers started to recognize and endorse the research potential of this method.

The focus group has the potential of providing a methodology of exploration, which allows participants to express their concerns within a context that is useful to the scientific community (Zeller & Carmines 1980).

Three different approaches can be adopted when working with focus group, as listed by Calder (1977): the exploratory, the clinical and the phenomenological approach. The exploratory option may be used to identify and structure new research questions raised by the group as important points to be covered and even to derive a guideline for future research (Angell & Klassen 1999). This approach is the one chosen in this work, as it is the intention of the author to expand the research in the reverse logistics field starting from the hints obtained from the Focus group. As Morgan (1997) has stated, the focus group interview can be part of an on-going, multi-method study when used in conjunction with individual interviews, surveys, experiments, or participant observations. Morgan & Spanish (1984: 253) suggested that focus groups "can add to other qualitative or quantitative data collection strategies".

3.2.3. FOCUS GROUP APPLICATION

The reason for using the Focus Group technique was to use it for orientating the research in the next stages, which could be conducted according to other methodologies, such as case study methodology, survey, etc. That choice would be made afterwards. Given that within reverse logistics the scope of aspects susceptible of deeper research are numerous, we tried to focus the attention, to obtain valid hints on the points of bigger interest, but also hints that were the outcome of knowledge and expertise of people with different perspectives and backgrounds. "Without a research focus, it is easy to become overwhelmed by the volume of data" (Eisenhardt 1989: 536.); there is an ever-present danger of "death by data asphyxiation" (Pettigrew 1988). This need for concentrating efforts in one direction was what induced us to adopt, as a preliminary and necessary step, the organization of a focus group.

Two different focus groups were intended, being guided by a holistic aspiration. The traditional way of handling the organization of a focus group within the reverse logistics field should have been to gather a group of people, intimately related with the particular and specific topic. They could come from several areas: they could teach it in their Faculties or education centres, they could devote their research time to the topic, their working life could directly demand from them to take decisions and responsibilities within the companies where they perform their professional activity, etc.

However, sometimes the membership, for a major or minor period of time, to a certain field may limit or constraint our capacity to objectively judge a specific issue. Sometimes a strong specialization restraints the ability to analyse an issue from a broaden point of view.

Therefore, our idea was to complement the traditional way of composition of the group, with also gathering information from another, different cluster of people, who although may not be so deeply related to the reverse logistics in particular, were strongly involved in other Logistics fields, with which the reverse logistics is related, is influenced and influences irremediably and necessarily. For instance, how could the return of products take place from the point of consumption to the point of origin otherwise than by using transport means? Counting on highly qualified people in transportation (qualification objectively recognised according to their professional carrier in transport field) would entail the chance of qualitatively extending the possibilities of obtaining different views, which could enrich and expand the perspective of the results.

Once this decision was made, the practical composition of the groups had to be worked out. We thought of two different ideal types:

- On one hand, scholars, people typically from Universities and devoted to research. Their particular field, although it should be within Logistics field, could or could not

coincide with the more specific one of the reverse logistics due to the newness of the field.

- On the other hand, we chose to listen to practitioners, people not linked with theoretical views but with the problems that they faced day after day, forcing them to take decisions. In this case, a more direct and deep relation to the reverse logistics was required.

At the same time, we thought that an international connection (e.g. within the European Union) was desirable, as the participants will be carriers of first hand local information, which doubtlessly will enrich the views of the other participants and thus, the outcome of the group. Therefore, the scholar group was given a pan-European nature, whereas the practitioners group was set to be local (some prior personal contact on the part of the University would simplify the access to the sites and people).

In the following, a brief description about the components of each group is given:

Descriptive profile of the first group participants:

Participant #1

- Professor of Industrial Management
- Research in Finland
- Area of interest: Quality Management, Product Development

Participant #2

- Professor of Logistics
- Research in Germany
- Area of interest: Production

Participant #3

- Professor of Production Operations
- Research in Sweden
- Area of interest: Business Processes, Logistics, Performance Measurement

Participant #4

- Professor of Physical Distribution
- Research in Denmark
- Area of interest: Logistics and Freight Transport

Participant #5

- Professor of Engineering Logistics
- Research in UK
- Area of interest: Engineering Logistics and Industrial Process Design

Participant #6

- Assistant Professor of Operation Management and Logistics
- Research in Spain
- Area of interest: Reverse Logistics, Costs

Participant #7

- Professor of Industrial Management
- Research in Finland
- Area of interest: Production Operations, Layout

Descriptive profile of the second group participants

Participant #1

- Position: Transport, LSCM and Commodity Manager

- Industry: Electronic

Participant #2

- Position: Logistics Manager Assistant
- Industry: Customer-made yachts

Participant #3

- Position: Materials and Logistics Manager
- Industry: Chemical

Participant #4

- Position: Logistics Manager
- Industry: Furniture and House Equipment

Participant #5

- Position: Logistics Director
- Industry: Electronic

Participant #6

- Position: Distribution Manager
- Industry: Food

Participant #7

- Position: Materials Manager
- Industry: Pulp and Paper

Participant #8

- Position: Logistics and Distribution Manager
- Industry: Beverage

In both groups the monitor (a person external to the chosen group members) disposed of a guideline prepared in advance, where some key questions to be proposed for discussion were included, while the author acted as the observer and secretary. However, after putting the talks in motion, his attitude was intended to be unobtrusive, so that the group would develop the topic autonomously.

Only two participants were unable to attend to the meetings. The basic questions were then sent by e-mail with the request of having them answered for the Focus Group meeting, so that their opinion could be debated for the rest of the members. Another consideration to be made was the time limitations for the Focus Group (one day) to touch a broader range of topics. In spite of the limitations, valuable insight was obtained.

3.2.4. FOCUS GROUP RESULTS

3.2.4.1. COMMENT ON THE FIRST FOCUS GROUP

In spite of the goodness inherent to the idea of joining experts from other logistics fields different to the specific one of the reverse logistics, the results drawn in this particular occasion were not too encouraging in the traditional sense of results expected from a Focus Group.

Although the evident willingness of the group was to actively contribute to this study, few of the professors had even previously heard about the term "reverse logistics" (probably because the specialization in their own research fields and areas of interest) and far less knew exactly what was implied.

One participant identified the meaning of the term with plain Recycling. When the meaning of the term was explained and the activities within its scope listed by the author (Repairing, remanufacturing, refurbishing, recycling, etc.), another participant, referring specifically to

Repairing stated that such activity has been done for aeons and, therefore, he did not understand what was special now for dedicating such attention nowadays.

The positive result that stemmed from this experience was, from the author's standpoint, to verify the fact that reverse logistics, in spite of the increasing attention received during the last decade, is a still an unknown term in many circles, not a familiar term, not even among closely related professionals.

3.2.4.2. COMMENT ON THE SECOND FOCUS GROUP

Components of the second focus group were all involved with reverse logistics activities in their respective companies.

In the following the main results are commented:

1. Firstly, the focus group members were asked to rank a list of five aspects according to the perspective they thought their customers might have. Quality of service surfaced as the facet, which according to the participants' opinion, customers would rate highest out of the whole list. This first feature was immediately followed (in this order of importance) by "speed of delivery" (which could be considered as an aspect within quality service, therefore a degree of consistency can be drawn from these two assessments), "variety of products", "price" and finally, "the return policies".

   If we take into account that many clients could consider the policies implemented by the company regarding returns as an additional feature of the customer service, the abovementioned results pointed to the fact that companies have not yet internalised the advantages they can themselves get from an effective reverse logistics implementation. Some companies still seem to ignore that return policies might result in substantive means of improving the service they offer to their clients, getting in return bigger impact in customer loyalty and, consequently, in sales. By making it easier for

customers to deal with returns, there is often more willingness to complete the initial sale (Daugherty, Myers & Richey 2002:86). This link between the implemented return policies and benefits from customers' performance would be enhanced, the more so when a liberal[25] and efficient return policy is backed by good capability of tracking the returned products. This, so-called "visibility" enables for accurate information at any time (e.g. Amazon.com's "where's my stuff" web-based tracking service). If customers may feel deceived for having got a commodity that must be returned, it will be advisable to avoid deteriorating the relationship even more by not providing good information about the status of the product.

A research attempt, in this case, could be devoted to confront the perceptions companies have about what consumers may expect, with the expectations from these consumers. The aim will be to detect misunderstandings between the parts involved in the service (the provider and the receiver). As a consequence of it, companies could more efficiently assign resources to the places that better please their customers.

In spite of the little importance given to the return policies in this first question (compared to the other four options), most of the practitioners in the meeting described the return policy in their companies as liberal.

2. Secondly, they were asked for the attitude of companies regarding reverse logistics. In their view, there is a sort of inertia in the corporations. Even if they are nowadays engaged with reverse logistics operations, this is admitted mainly to be as a consequence of a reactive stance. Environmental legislations passed in recent years have shifted the responsibility on producers for taking back their products, putting pressure on them. Therefore, they have implemented reverse logistics procedures in order to adhere to the legal obligations rather than to adopt a proactive performance. Some other drivers were mentioned in the meeting, such as "customer requirement" or

[25] Liberal policy means that the company has not set a lot of constraints for the returns to be send back.

"to recapture value", although these reasons were not as common among the participants as the legislation was.

In the same vein, the lack of a specific resource allocation within the companies for reverse logistics purposes (except for one of the companies represented) was mentioned. This fact is another symptom of the passiveness stated in the previous paragraph. The fact of the responsibility of reverse logistics matters being spread out over several departments within the companies (purchasing, forward logistics group, after sales service, production department, etc.) enforces the same idea. It is probably important to say that the Logistics responsibility was also typically shared out among purchasing, import/export, shipping/receiving, operations, etc. Therefore it was not a wonder if reverse logistics was divided too.

The claimed lack of high corporate priority in this arena is another sign of indifferent attitude; in fact, not having specific resources devoted to reverse logistics activities enforces this lack of priority. This result is in line with the results obtained from a survey to 311 logistics managers by the reverse logistics Executive Council (Bayles 2000:261) in which, the 14% of the managers interviewed considered the topic of "relative unimportance", refusing therefore to reckon any important priority to it. They do not concede credit for reverse logistics efforts to translate into reduction of costs, increase in profitability or enhancement of relationships with other channel members (Daugherty *et al.* 2002).

Another future research direction that rose from this Focus Group could investigate the reasons why there is this lack in corporate self-motivation or emphasis when it comes to face return products management. Possible hypothetical reasons include lack of information, lack of perceived or achievable economical advantages, high costs, organizational barriers, cultural constraints, sector of business, etc. The predominant view seems to be that reverse logistics poses a burden on the organization, generating

moreover additional costs from the specific operations needed (collection, sorting, storage, etc.).

3. The question of costs was tackled next. A noticeable unanimity was observed regarding the lack of accurate information about reverse logistics costs. Koster *et al.* (2001) detected the lack of attention paid in literature on financial matters regarding reverse logistics. Some participants underlined the fuzziness regarding the concept of reverse logistics itself and therefore the difficulty to assign costs to the right reverse activities. Some others drew the attention to the lack of a responsible-of-returns person, under whose authority the tasks, and so, the costs, could be concentrated or referred to. In Meyer' s article (1999), the president of one of the most important third-party providers of reverse logistics states how often in organizations everybody is involved in returns but nobody is in charge. The same idea holds in some more recent pieces of work (Richardson 2001). Among the experts gathered in the Focus Group, the majority agreed that this assessment still reflected the actual situation, regardless of the sector.

   Finally, in line with the assessment made by Goldsby & Closs (2000), some members agreed with the mystery in which remains about the true cost of reverse logistics, although this fact could maybe also be extended to other parts of the firms. Suffice it to say, that, of the companies represented by the managers taking part in the Focus Group, five did not use any cost accounting system for keeping track of costs generated by the reverse logistics activities, while the remaining three companies used an "approximate" method. None of them was recognized to be utilising, for instance, ABC.

   Connected to the costs information was also the decision about whether to undertake the reverse logistics processes in-house or to outsource them. It is difficult to adopt any sound solution without being able to evaluate third party or in-house options for reverse logistics management on a costs information basis.

Consequently, it seems critical to find out what are the main obstacles for the companies to implement costing methods, which would enable managers to adopt different operational and even strategic decisions. Also the potential benefits derived from them influence the decisions. These benefits should also be categorized and analysed in further research. Only after knowing the financial implications of each activity, process, or decision, the company will be able to focus effectively on reducing costs and trying to increase benefits.

4. Information about tracking the items, their status, their value, their final point of consumption, etc. was considered another strong constraint in returns management. Although lack of control on these issues may pose a company with serious risks, most of the representatives confessed not to be using any technology (software or hardware) to assist in the returns handling -only EDI and bar codes were used by two companies. On the other hand, there is not yet commercial software specific for reverse logistics available. The software some of the respondents had heard of was a proprietary software system, tailored for each of a very few companies that were having it in use.

Returns information is valuable both for the supply chain members and for their customers. It may help to reduce abuse from customers when companies adopt a more liberal return policy. Historical databases also allow for easy analyses on defects coming from the same suppliers, periods of the year in which returns take place more frequently (information that also helps to reduce forecast errors and it is also necessary for reducing uncertainty in inventory management) and so on. From the customer point of view, ICT produce more accurate order status knowledge at any time, considered by some as an additional customer service feature. Internet was a tool thought to be poorly utilized according to the experts, who manifested their trust on future increase of applications. Without this computerized information is difficult to get reliable indicators by means of which to detect easily which variables stand out and why. Another drawback pointed out was the use that could be given to this information for evaluating reverse logistics performance, so that measures could be taken against detected

inefficiencies. No evaluation was made in most of the companies represented in the meeting, and the reduction in raw materials was the sole indicator followed in those where any evaluation attempt was made.

Generally it seems that software programming geared to tackle the returns should be encouraged as an important future issue. On the other hand, other technologies already available should also be promoted so that information flows could support reverse activities in a reliable way.

5. Although most of the representatives dealt with long return processing cycle times, only one thought shortening the entire life cycle of the product as a sound reason for being involved in reverse logistics practices.

   Life Cycle Analysis is a powerful tool, which is also receiving increasing importance as a consequence of environmental concerns. However, its use is not yet largely spread. More research needs to be conducted to specifically address this issue in different sectors and industries.

6. Finally, when major challenges in performing reverse logistics activities were tackled, two main problems were mentioned: the difficulty in achieving economies of scale and forecasting the right quantities of returns and periods of time in which the returns will take place. Literature has already been sensitive to both problems (Guide *et al.* 2000; Koster *et al.* 2001).

   Although the percentage of returns has been estimated in some studies (e.g. Rogers & Tibben-Lembke 1999), on average, as 5% on the sales figure (their estimate "may be as high as 25–30% in some business segments, even up to 50 % in magazine publication"), companies represented in the Focus Group agreed in general upon far smaller rate.

Therefore volumes may be insignificant for some businesses to reach economies of scale, although still a possible area where to cut costs down.

Some companies impose fees on customers, which may be a deterrent to get customers involved in returning products so that increased volumes could be reached. This situation did not apply to any of the companies that intervened in the group though. The quest for not achieving economies of scale should be imputed to other sources (possibly positive ones: i.e. good quality of products). All the same, the attention was driven to means by which economies of scale could be reached. Fostering collaboration among different partners in the chain was the straightforward option. Partnerships among firms within the same industry (as it already happens within the beverage industry in Finland, or DSD[29] in Germany) or among firms whose products could be compatible of being managed together were some of the hints given. Centralized Return Centres run by several partners are an example of this collaboration.

Third party logistics providers are expected to more easily reach economies of scale as they may aggregate returns from several customers and gain superior expertise and information, which all may translate into lower costs (Razzaque & Sheng 1998).

3.2.5. CONCLUSIONS

By means of the Focus Group technique, some experts explored the future research areas within the new field of reverse logistics. Although its growing importance is remarkable, its role does not yet seem to be fully recognized in certain circles. As a consequence, further research should be devoted to explore what is impeding reverse logistics knowledge and what are the mechanisms by means of which the technology spread could be accomplished most efficiently.

---

[29] Duales System Deutschland: the German organization responsible for collecting and recycling consumer packaging.

However, involvement with reverse logistics practices also needs to be fostered. In this line, some relevant obstacles have also been revealed; the urgency for methods, which provide with accurate costs information, given the critical role costs play when it comes to take decisions within companies. In spite of a lack of these methods, a strong feeling exists that reverse processes are costly, discouraging a proactive stance. Thus, it is necessary to find solutions that would ease the calculation of these costs (or, alternatively, ways to increase the revenues to offset the costs), allowing to reduce and to manage them. Neither do measures devoted to evaluate reverse logistics performance seem to be largely used. Generally, what is not measured, cannot be improved. Other shortcomings, as the lack of computer programming support or the life cycle analysis, were made evident. Specific reverse logistics software or IT solutions would be valuable in understanding this cost information, although it would not be the only benefit. Eventually, it would also facilitate both the use of the LCA (making the follow-up of products and the forecasts of returns easier) and the increase in customer service (providing more accurate information).

Each of the points considered were posed along with proposals for future research areas, so that companies could be helped to overcome challenges of this emerging discipline.

3.3. CASE STUDY APPLICATION

Under the heading of "Case study application" different case studies are comprised by means of which various elements inherent to the implementation of reverse logistics have been explored:

1. The first case study (Section 3.3.1) focuses on the role played by reverse Logistics in two companies, which offer the recovery option of repairing within their customer support pack of services. The purpose was to understand the extent to which

organizations internalise the potential benefits of reverse logistics practices in order to improve their strategies in the market.

2. Because environmental management practices introduce changes in operations policy of organizations (Azzone, Bianchi, Mauri & Noci 1997), two additional case studies (Section 3.3.2) were carried out in order to understand the impact and significant outcomes in procurement policies that may have resulted from the involvement in reverse logistics practices.

3. Finally, we wanted to examine what were the induced effects on reverse logistics decisions from the degree of previous involvement in environmental standards. By means of an additional case study, these effects were tracked (Section 3.3.3).

In summary, the overall purpose of these studies was to explore and evaluate the reverse logistics phenomena in real world settings in order to confirm or adjust the framework given by literature.

3.3.1. REVERSE LOGISTICS IN REPAIR CUSTOMER SUPPORT. A CASE ANALYSIS.

3.3.1.1. INTRODUCTION

Customer support enhances the value of the purchases (Goffin 1999), contributing to the good reputation of a company and the achievement of customer satisfaction (Emerson & Grimm 1996; Pfohl & Ester 1999; Botter & Fortuin 2000). A multitude of services may be included under the umbrella of customer support (installation, user training, documentation, telephone/on line support, inspection, maintenance, daily assistance, parts supply, repair, upgrading, performance optimisation, disposal, etc.). One important facet within the scope of customer support is the activity of repairing. We focus on those characteristics that,

within reverse logistics, facilitate the repairing activities in a company, given the role played by Logistics in customer service (Schary 1992; Kearny 1994).

A major difficulty when this topic was planned was that both disciplines (customer support and reverse logistics) necessitate further efforts in research (Pohlen & Farris 1992; Hull & Cox 1994; Johnson & Wang 1995; Guide *et al.* 1997; Ashayeri, Heuts & Jansen 1999; Goffin 1999; Gungor & Gupta 1999). As far as customer support is concerned, several authors have admitted its importance from different perspectives: as a source of revenues, as a means to achieve customer satisfaction, as a tool providing competitive advantage and as a information source for new product development. Nevertheless, Hull & Cox (1994) still state it to be a neglected area, where only a small number of publications exist.

As what regards reverse logistics, we have already remarked how this discipline is increasingly being recognized as an important research field. However, many areas do still require further investigation, and there is practically no previous research on the repair activity (Ferrer & Whybark 2001a).

With this section we intend to reduce the gap in these fields by a study conducted in two different companies, in different sectors of activity, but linked by both offering the repair option within their after-sales service. The aim of the study was to investigate the extent of their reverse logistics deployment in repairing context. In addition, we aim at identifying the inducing factors when it comes to choosing the reverse logistics channel. On the other hand, we analysed the circumstances that facilitate the internalisation of environmental legislation regarding value recovery.

Although for companies that operate worldwide the problem becomes even more complex and important (Ashayeri *et al.* 1999), the case study shows how these companies have reacted to this need of adaptation and to their customer demands and how and why these reactions may vary from one to another.

3.3.1.2. REPAIR, PRODUCT, REVERSE LOGISTICS AND SUSTAINABLE DEVELOPMENT

Not all products do have identical needs regarding repair services nor, therefore, do companies require the same infrastructure design for offering such a service. In certain cases, depending on the typology of the product, repair costs may exceed the disposal and replacement costs, whereas in other cases the situation may be quite the opposite. Lele (1997) categorizes products in four after sales segments according to the types of cost (fixed and variable regarding the duration of equipment downtime) the customers face when the product fails (see Figure 6).

According to this model, the option of repairing is more appropriate for products such as personal computers and their peripherals, large household appliances, etc., in which, fixed costs are high relative to variable costs generated from a failure.

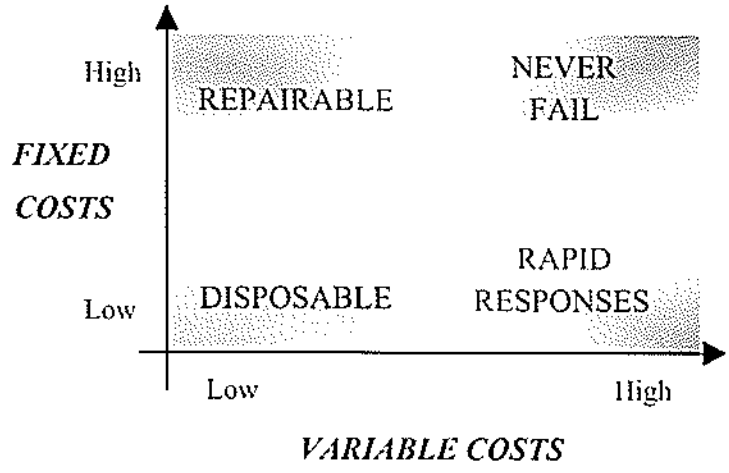


Figure 10. After-sales service segments (adapted from Lele (1997)).

Repair is also an option when variable costs are important if compared to fixed costs (e.g. a photocopy machine). Knecht, Lezinski & Weber (1993) contend that if equipment fails, fast and efficient repair is essential in many markets because downtime costs run typically at anywhere from 100 to 10.000 times the price of spare parts or service. With these numbers in mind, it is easy to infer that customers will not be willing to take risks. This holds true

unless either the supplier is able to guarantee the availability of a replacement unit while the faulty is being repaired, or the logistic chain is designed in such a way that the repairing is expeditiously made (either in the customer premises or in the company's facilities).

When both categories of costs are low, the option of disposition seems to be the most cost effective (the decline of acquisition costs, shorter life cycles and increased reliability shifted some PC models to the disposable group). Finally, there are products in which the option of failure is not affordable and, consequently, contemplated. In this last case, only on-site repair personnel carry out repair.

From the previous classification, we have focused on those products eligible for repairing activities, i.e. repairable and rapid responses products. In fact, companies dealing with this kind of products need sometimes put strong emphasis on this facet of customer support in order to reach competitive edge regarding their competitors (Lele & Sheth 1987; Hull & Cox 1994).

Apart from the type of product, there are more factors that influence the support channel decisions (Goffin 1999). These include the need to resort to additional income sources (derived from repair service offer), the desire to control the quality of the service (Mallen 1996), and the high costs from the implementation of own channels.

The manner enterprises organize reverse logistics channels oriented to repairing activities varies depending on the cases. Loomba (1996) stated the existence of five different kind of channels: direct support from the factory; direct after-sales network; channel intermediaries; authorized, independent third parties; and, finally, some combination of the four previous possibilities. In addition, Loomba (1996) contends that the election of customer support distribution channel is closely linked to a company's sales channel.

Although case studies may be found in literature, they do not pointing out (as is the objective here) the inductor factors for each model. Hull & Cox (1994) studied the role of customer support in six US companies in the electronics and computing sector. Since all six companies used the direct channel, this study provided no information on the role of different channels in customer support. However, it provided six examples of successful use of a direct channel and demonstrated the importance of good information exchange and parts management. Fortuin & Martin (1999) also make a distinction between three types of technical systems that require service parts: technical systems under client control –machines in production departments and transport vehicles in a warehouse–, technical systems sold to customers –computers and medical systems in hospitals– and end products being used by customers –TV sets, PCs, motor cars and vacuum cleaners.

It is maybe in its place to note here that the names of the case companies are for confidentiality purposes invented by the author, and, despite the possibility that there might be companies with similar names, these are NOT the real names of the companies described. Any similarity with eventual companies in existence with the same names is purely coincidental.

3.3.1.3. CASE STUDIES

Case 1. DomesticA

The company DomesticA, located in a Nordic country, is part of a global corporation. This group is one of the world's largest producers of powered appliances, which fall under the category of repairable products, already explained in precedent section. Group sales take place in more than 150 countries around the world. The group's customers are retailers and final customers whose range varies notably from professionals to institutions, either national or international. The group is fully engaged in improving its environmental performance, as proven by the following indicators: approximately 58% of the company's factory area was ISO 14000 certified at the end of 2001; all sites with at least 50 team

members are required to implement EMS and to pass the exam for the international ISO 14001 certification; newly acquired units have three years from acquisition to accomplish the process. Recent WEEE[30] Directive, which establishes producer responsibility for financing of recycling and final disposal of many electrical goods, affects almost all household products manufactured by the company, this corporation being one of the promoters of the equipment makers responsibility.

As far as reverse logistics are concerned, and as a general rule, products sold by DomesticA are never sent back to the factory. Only does the company accept responsibility for collecting and taking back to the factory appliances, when they have been damaged on transit or when they are still covered by warranty period. If any of those two conditions are satisfied, the company does not take part in returns.

During the lifetime of the product, local authorized service points are in charge of all the white-ware being repaired. According to the manager of one of these district service points –a private company-, "about 999 of these appliances out of 1000 are possible to repair". The one that is not possible to repair is sent for scrapping locally.

At the end of the product life, the customer is usually the one who gets rid of the item locally. The company contemplates only two exceptions at this point of the lifetime of the product: firstly, when products contain chlorofluorocarbon gases (CFC); the second exception applies only in the few extremely rare cases where the breakdown of the machine has caused personal injury to the user. In the latter, the machine is sent to the factory with the aim of being checked and studied by the risk management department.

The lifetime of these products is a question difficult to respond to because, although technically their lifespan may be estimated to last a certain period of time (between 7 and 15 years on average), the utilization from customers considerably affects their effective life.

[30] Waste Electrcial and Electronic Equipment.

On the other hand, in actual markets, technical cycles far overcome market cycles, as new models are launched in less than 10 years. In the 80% of the cases, customers face the need of getting rid of the old unit because they bought a new one (market is becoming more and more a substitution market (Gertsakis *et al.* 1998)). In this situation, when the retailer delivers the new purchase, he collects at the same time the unit to be replaced, although it is the customer who bears the costs for scrapping it by paying 27 euros. Once the retailer premises house an amount of 80 units (in case of washing machines or refrigerators), the retailer phones to the company. The company then sends a third party logistics provider who collects the products from the retailers' store and takes them to his own warehouse. From there, products are shipped to a central warehouse that the company has operating for the whole East Europe area. From there, whether by train or by truck, returned products are sent further to the central European recycling centre in Germany. The flow from a country like Finland to this centre is about 80-100 units per year.

Although the manufacturer has not yet any legal responsibility to take back his products (not before the 13th August, 2004), the company started in 1999 to recycle them. At that time, recycling this sort of products was not yet possible in Finland (as it is today). Therefore and in spite of transport to Germany not being exempt from bureaucratic obstacles, a German recycling centre was chosen (see Figure 11 for the whole process).

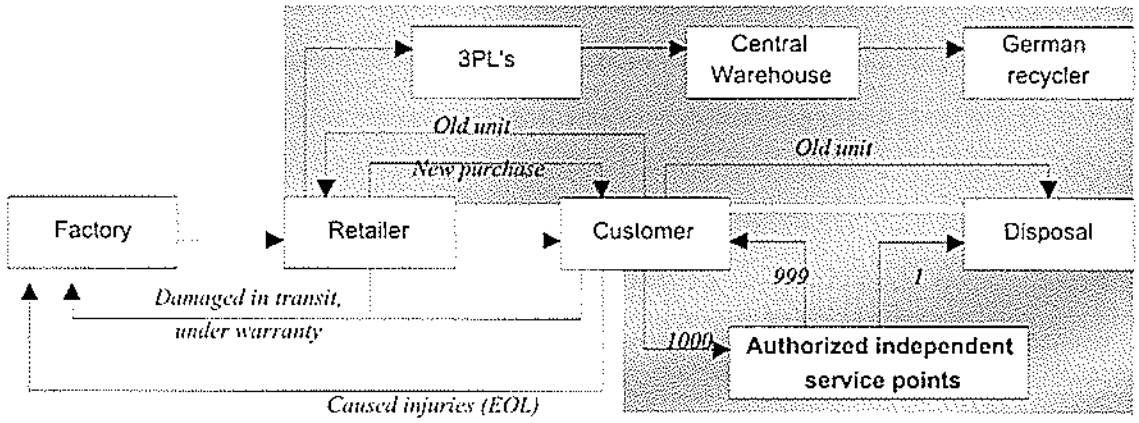


Figure 11. Organization of flows at different stages of product life.

For all the transports described above, third-party logistics providers' services are used.

Apart from the material recovery achieved by means of the recycling activities (not operated in-house), the company has until recently discarded the possibility of establishing the dismantling of used appliances as a regular source of spare parts. Some possible reasons may have been behind this posture:

1. On one hand the products manufactured by this company fall under the end products for which clients are anonymous and the demand process of required service parts needed for repairing activities is an erratic process. These facts make very risky and costly the organization of a complete structure for supporting returns.
2. On the other hand and according to one of the managing director interviewed, household appliances do not respond to the type of product that could be considered as complex product; they are quite simple. The electrical motors or compressors that could be recovered at the end of the lifetime of these appliances, are no longer interesting because of their worn out condition. The remaining components have usually a much shorter life-time: scratches or dents, produced during the utilization by the consumer are worthless to fix, the more so since these defects often are in the external parts of the product; these external parts happen to be the most quickly fashion-changing parts (colours, models, change fast). As a consequence of it, they were in most cases led to a metal recycler.

As a result of extensive research to minimize the impact of its products, apart from recycling activities, the company has recently included the remanufacturing/refurbishing of old appliances as an extension of its product take-back program. The introduction in 2001 of refurbishment of white goods as a pilot experiment was an important step towards minimizing the environmental impact of appliances. More than 4,000 damaged or used products that otherwise would have been scrapped have been refurbished and resold to consumers. This offers them the choice of cheaper appliances while optimising material use

and generating profits for the Group. After a first experimental project, three other similar remanufacturing/refurbishing plants have been put in operation worldwide.

Case 2. PowerS

PowerS manufactures power plant stations and marine engines. It has presence in 140 countries: subsidiaries in 60 countries [production plants in 3 of them, spare part warehouses in other 3 and workshops in more than 50] and local service network offices[31] in the remaining 80 countries. In addition, there is an after sales centre in Finland that gives worldwide coverage when local service offices are not enough. The company does not work with independent service points.

PowerS takes care of the design (the manufacturer is increasingly looking for modular solutions[32] and easy disassembly procedures), manufacturing of critical parts (the rest are purchased), assembly, sales and maintenance of the products. One key element of the company's customer support is that it offers not only a total installation service, but also a full range of customer tailored after sales solutions.

Although, no far ago the strategy of the company service focused on selling spare parts, today's view has changed towards offering a good repairing and reconditioning service[33]. This shift to service has also translated into recent acquisitions of former, very specialized service competitors, creating a solid worldwide net for this kind of services. The main driver behind this change in the company strategy has been customer demands. Customers benefit from lower pricing in reconditioned items while the same quality as new is guaranteed. The outcome of this process has been an increase not only in amount of

[31] Difference between workshops and service network offices mainly stems from qualification of personnel (basic knowledge in service network offices, more skillful in workshops) and the variety and amount of spare parts kept in stock (bigger in workshops). However in both of them, activities of repairing and reaconditioning are carried out.
[32] Company profile 2001, p. 7.
[33] Only in Service division work 5.644 people world wide: some are engineers who travel to customer's sites, others take responsibility on spare part stock and the rest are technical people.

repaired or reconditioned items but also in a more ample range of items being subject to these activities. Customers may however resort to free service offices. Prices of parts and services are lower than from PowerS; however, these free service offices do not offer warranty at all.

Service is therefore a strong focus of the company. "The total service concept and the company's in depth knowledge of its customers further increase its competitiveness"[34]. Customers are not anonymous. The size of products and their high price are factors that influence on the yearly total sales (there is not a massive consumption of this kind of items). On the other hand, the highly customized service solutions allow for a close relation all the product life cycle long (10-15 years).

The Environmental Management System used[35] by 2/3 of the subsidiaries (PowerS included) is in accordance with the ISO 14001. Environmental matters are a subject of concern for both marine and power plant owners. It also complies with International Maritime Organization (IMO) and ISO 9001:2000 standards. Environmental issues are taken care of by Quality Department. Reverse logistics operations are concern of After-sales Department.

PowerS responds quickly and repairs engines on-site. When a breakdown occurs, the nearest service unit (capable of giving the needed service) sends their service personnel. Except in very exceptional cases (only two engines were sent back last year), because of the size of the items, the product is not sent to the service offices or workshops (leaving alone to the manufacture plant). The service personnel are qualified in every case to disassembly the item but not always are they capable of accurately evaluating the importance of the damage. This represents a big challenge for the company which sometimes assumes the risk of taking back the old critical parts and replacing them either with new or with reconditioned ones (the choice entirely rest on the customer).

[34] Annual Report 2002, p. 27.
[35] By September 2002.

The company is not interested in "not critical parts". The costs of transporting them back far overcome the value that could be recovered from them. The disposal of those is at customer expenses. No regulations have still shifted the responsibility for taking back EOL products to the manufacturer.

Old critical parts are sent to the service office premises were the assessment on their final condition will be made. The uncertainty around the state of the used parts was highlighted as the most challenging task posed by taking back operations. The examination at customer premises is visual and based on the expertise and business view of the service personnel. Once in the service office facilities, personnel are supported with special equipment for accomplishing the task. Reconditioned parts are resold at lower prices.

When the reconditioning is not possible, parts will be discarded. Because of their high metal content, recycling is the solution chosen. Recyclable items will be pile up outdoors till volume allows a full load truck. Revenues from selling scrap to the local recycler are offset by transportation costs.

Complexity of product, as far as critical parts are concern, is important. Under this circumstance, the need for exerting control of the chain is bigger and the channel chosen is a combination of direct support from the factory and direct after-sales network. It could also explain why, even if some modules need to be sent on PowerS suppliers, the module is first chipped to PowerS so that the after-sales service can keep trace of the performance of every component in their engines. In addition, this constitutes a valuable source of information both for purchasing department (suppliers evaluation) and for R+D department (future product enhancement).

Transportation service providers operate shipments of parts.

Another important aspect within the customer support policy relates to information transfer. The traditionally paper-based communication is progressively being substituted by other

cheaper, quicker and more flexible platforms, mainly Internet-based. With this system data are much more easily and comprehensively collated, which is crucial for early recognition of product problems.

3.3.1.4. DISCUSSION

Next we accomplish a comparative analysis between both companies. As differences are stated in relation to different factors, we will formulate propositions, which will be tested in future large-sample studies.

The type of product affects the reverse logistic design alternative chosen for supporting the customer service of the firm. Thus, in the first case, in which households' appliances do not respond to the type of product that could be considered as complex product, the manufacturer does not need to exert a tight control over the logistics needed to support the customer service (Armistead & Clark 1992). From the list of five different channels stated by Loomba (1996), the after-sales channel that fits and is usually used in this kind of situation is authorized, independent third party. That was also the solution adopted by DomesticA. In the second case, products become more complex and the channel finally chosen is a different alternative. This results in the following proposition:

Proposition 1: *The externalisation of repairing activities heavily depends on the complexity degree of the product.*

According to the categorization made by Lele (1986), both companies manufacture products of different nature: "repairables" in DomesticA and "rapid response" product in the case of PowerS. Our observations coincide with what was suggested by literature in the sense that the type of product and the likelihood of outsourcing the repairing activities are correlated (Guide *et al.* 2000). From it the following statement is derived:

Proposition 2: *Outsourcing-repairing activities is more likely in repairable products than in rapid responses products.*

A key characteristic for rapid response product to be considered different from repairables is that customer service is seminal (Lele 1986). This service is critical when it comes to define internalisation level of repairing activities. Thus, in the first case study these activities were mostly outsourced whereas in the second case the control exerted on them is greater. From this we stem the following proposition:

Proposition 3: *The lesser critical is the customer service in a company, the bigger the likelihood of outsourcing its repairing activities.*

Although the second company shows a bigger tendency to internalise, the first also adopts this strategy when there is a risk of its image resulting damaged and therefore, its future market share (CFC products, items whose breakdown has injured the customer). Literature has also conceded that internalisation is more likely when consequences may affect the normal development of the business strategy (Rondinelly & Berry 2000). This idea does not however preclude the fact that third logistics providers perform most of the shipments. For instance, Quinn & Hilmer (1994) observed that other firms might better accomplish activities with environmental implications such as the handling, storing and transporting of hazardous materials, because these tasks fall outside the competency of most companies. From previous discussion, the following proposition is derived:

Proposition 4: *Manufacturing companies usually internalise those repair activities linked with products, which could potentially deteriorate the company image.*

A characteristic of the reverse logistics and repair service cycle is the uncertainty of supplies: usually buyers do not know when a 'line' item will be coming back, nor do they know its condition (Blumberg 1999). In our first case, given that customer are anonymous, the implementation of a complex reverse logistics structure is highly risky. However, for

local retailers the characteristics of the returning process may be less uncertain. Consequently, it seems these local retailers to be more conveniently prepared to take care of these tasks. In the second case, however, the deep customer knowledge is key for the company competitiveness. This justifies the following proposition:

Proposition 5: *The bigger the uncertainty about volume and condition of repairable returns the bigger the probability of outsourcing the repairing service and the related reverse logistics.*

A characteristic of the reverse logistics and repair service cycle is the customer specific focus: the provider of reverse logistics services must really know and understand the characteristics of its customer base (Blumberg 1999). Actually, this knowledge about the customers stands in the retailers. Consequently, it would be convenient to make the most of their specialization regarding this knowledge. However, in the second case, the company itself conducts the repairing of the returns since it has a deep knowledge of them, its competitiveness being based on it. This rational lead us to the next proposition:

Proposition 6: *The outsourcing of repairing activities in a company is more likely if the knowledge about its customers is scant.*

Both companies have modular designed products. This verification coincides with assessments found in conceptual literature in the sense that, value recovery activities (and within them, repair activities) are favoured by the utilization of modular designs (Ayres *et al.* 1997). From it, we derive the following proposition:

Proposition 7: *Companies with strong involvement in value recovery as a consequence of an advanced environmental commitment, introduce modular design in their products.*

Product characteristics influence on the choice of the value recovery alternative (Ferrer & Whybark 2001a). Thus, in the first case, technical life of components is shorter than economical life. In PowerS case, however, some materials characteristics make recycling the most appropriate option and respondents pointed out this reason as the justification for doing so. From it, we formulated the following proposition:

Proposition 8: *Recycling is an adequate value recovery option for those products with specific technical characteristics and for those where technical life of their components is shorter than economical life of the whole.*

3.3.1.5. CONCLUSIONS

The goal of our case studies was to analyse the interrelations among repairing activities and reverse logistics. With this aim in mind, two companies were chosen, manufacturers of products with different characteristics regarding their repairing needs.

We have verified that the type of product, of their components, the strategic implications and the relations with customers, among others, delineate the reverse logistics networks adopted by the companies, the importance conceded to repairing activities and the way they prevail on other recovery activities. Confronting these findings with previous literature, we have drawn several propositions, which intend to be empirically verified in subsequent large-sample studies.

Although this work allowed us to get significant deeper insight of the topic, some related limitations may be formulated. On the one hand, its external validity, which will be avoided in future large sample based studies. On the other hand, companies mirrored in this analysis were the ones willing to collaborate out from a great number of them. Thus, the results obtained could be affected by an optimistic bias since those companies which did not want participate could enjoy a disadvantageous position.

3.3.2. EFFECTS ON PURCHASING FUNCTION AS A RESULT OF RECOVERY ACTIVIES

3.3.2.1. INTRODUCTION

The importance given to purchasing function seems to have been subject to certain cyclical patterns (Farrell & Heinritz 1981), going from stages of unobtrusiveness to others in which, given the circumstances of the markets, it has played a critical role in the corporate development. Purchasing function, however, should play a major role in corporate strategic planning (Heberling 1993), the more so, in the last decades, as the recognition of both scholars and senior managers demonstrates (Keough 1994; Humphreys, McIvor & MvAleer 2000; Zsidisin & Siferd 2001).

Over its last century history, purchasing has adopted several strategies to face the different challenges encountered in normal business, such as competition, globalisation, periods of shortage, etc. The critical influence of purchases on the final costs of goods (costs, which may easily represent the lion's share in many industries (Leenders, Fearon & England 1989)) or the involvement of purchasing department with the formation of trading partnerships, among others, were some of the drivers behind.

Next future scenario seems to be challenging too. Green supply-chain management constitutes one of the seven trends in international logistics in the years coming as Skjoett-Larsen (2000) underlines and this rapidly-spreading phenomenon will have to be fully internalised in corporations management which, undoubtedly will affect on their purchasing strategies.

Improved environmental performance, demanded from both public institutions and customers over the last decades, compels firms to take responsibility of the environmental impact of their products and technologies. This social and economical momentous change may suppose the next major step in the evolution of supply management, this step being

still in its infancy. If first business' attitude to these environmental issues was described as "resistant adaptation" (Walley & Whitehead 1994), firms are slowly but increasingly recognizing the competitive advantages that may stem from environmentally friendly practices (Winsemius & Guntram 1992). In this process, firms and within them, purchasing managers, are prompted to reassess their current purchasing strategy (Min & Galle 2001). Not doing so may prevent them to comply with an essential prerequisite for their conduct in the future market.

Because the topic of environmental and recovery issues is relatively new, published academic research do not still cover full range of these aspects. The link of these two issues with purchasing is even more recent research topic. These circumstances make case based research methodology a successful tool to gather valuable information upon which grounded theory can later be built. This is therefore the research method chosen for analysing the effects on purchasing patterns of two real companies.

This 3.3.2 Section is structured in six sub-sections. After the first one having been devoted to provide an introductory approach to the subject, sub-section two narrows the topic by focusing on the reasons why the involvement in recovering manufactured products affects the normal activities of purchasing personnel in a company. Third sub-section serves at gathering, from a literature review, some of the answers companies have responded with, and, what effects these responses have cast on buyer/suppliers relationships. The methodology utilized and its justification are explained in sub-section four. The field research carried out in two manufacturing plants is expounded in sub-section five to finish, in sixth sub-section, extracting some conclusions and suggestions for future research.

3.3.2.2. OVERVIEW OF RECOVERY ACTIVITIES INFLUENCE ON PURCHASING FUNCTION

The activities carried out as a consequence of the recovery process are found in literature, associated with the terms: Product Recovery Management (PRM) and reverse logistics. In

Section 2.1.2 we already put forward Thierry *et al.* (1995: 114) definition of PRM as all those activities that encompass the management of all used and discarded products, components, and materials that fall under the responsibility of a manufacturing company with the objective of recovering as much of the economic (and ecological) value as reasonably possible, thereby reducing the ultimate quantities of waste. Five different alternatives were distinguished within PRM's scope: repair, refurbishing, remanufacturing, cannibalisation, and recycling (see Section 2.2.3 for their purpose).

Reverse logistics (or reverse distribution) could be interpreted, to certain extent, as the operational side of the PRM (Bellmann & Kahre 2000). Reverse logistics focus on product returns flows[36] sent by one member of the supply chain to any other previous member of the same chain. In addition, flows taken place out of the original chain, whose origin is located in the original supply chain, are also included provided they are the antechamber of activities of repairing or recovering added value or material (Fernández 2003a).

Regardless the feasible option to apply to a specific item, purchasing department needs to work tight with other departments, direct or indirectly, involved with returns. Justifications come from two different perspectives. On one hand, if a returned product requires to be repaired, refurbished or remanufactured it is likely that some parts or modules are needed to be replaced and so, provided, to complete the process of respectively, fixing or bring used products up to specified quality standard. Purchasing has the responsibility of guaranteeing the procurement of the new components or materials needed for these operations when inventory on hand run out of them. Consequently, these return-related activities represent a new source of demand to be satisfied, in addition to the demand from the market. Purchasing has a role to play in it.

On the other hand, if the returned unit is entitled only for cannibalisation, again purchasing department should be informed on the amount of reusable components that are entitled to

[36] and related information.

be recovered and thus available for putting into inventory, as this supply will reduce the need of external purchases. Recycling pose a similar situation although in this case, the amount of raw materials will be affected instead. In these two latter cases, firms come across a new source of either components or materials supply that need not be purchased. A side effect also observed in some cases is that recovered parts may also be sold as spares, therefore a second new source of demand may also appear to be handled with.

Purchasing employees require good information flows to adjust the needs that must be satisfied from external suppliers. Using the terms identified by Ballou, Gilbert & Mukherjee (2000) regarding coordination in the operations management, intra-functional coordination (as several different actors are involved: purchasing, material control, production, sales, distribution) if always advisable is, in this case, critical, leaving alone if the purchasing decision-making process is centralized.

When returns were not taken into consideration, the flow of materials within the firm could be represented as in the following Figure:

Figure 12. Material flows in traditional context.

Complexity of traditional purchasing planning stemmed from factors such as, sales forecasts, processing times, inventory management techniques, delivery times, etc. The task was not yet easy to cope with. However, the inclusion of returns implies a remarkable increase in its inherent planning complexity. It suffices to look at the following Figure, which illustrates the additional material flows generated from the inclusion of returns considerations:

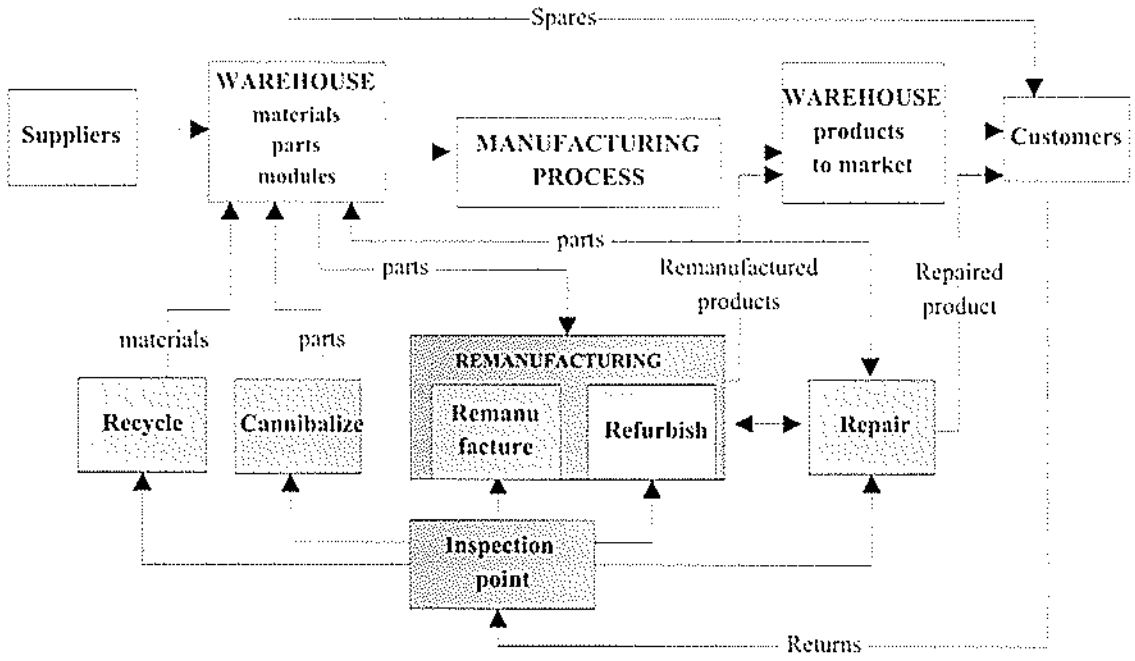


Figure 13. Material flows when returns are considered.

The higher number of flows does not only provoke the increment in complexity. So far, nothing has been still mentioned about the uncertainty surrounded the process. Uncertainty in returned product supplies, inherent to the reverse process, is a unique characteristic of this scenario. Uncertainty is twofold: firstly, managers need to cope with the lack of information regarding quantities of returns, variety, wear state of items and times when they will be recovered; secondly, return units need, in most of the cases, to be disassembled. Only after getting access to the interior of the returned product is it possible to know about the condition and thus, the availability of certain module or part. This information is required to know the stock on hand and therefore to order extra needs to suppliers within acceptable margins of error.

Under certain circumstances, the described level of uncertainty may be reduced. For instance, companies whose core business consists of leasing and renting are able to forecast

more accurately, when and how many of their products will come back (Ayres *et al.* 1997). Another situation, in which uncertainty diminishes, takes place when the fact of returning the products is subject to the concession of a Return Material Authorization (RMA) by the Original Equipment Manufacturer (OEM).

Apart from these special cases, returns convert inventory planning in a difficult task and consequently, incorrect purchase decisions may drive company to disastrous economical and organizational performance: not enough material to feed production process, to many stocks on selves getting obsolete along with important sums of capital invested on them, etc.

Next section tackles with some responses, changes, strategies and reactions that academics point out in literature, regarding purchasing function within the emerging environmental and recovery scenario.

3.3.2.3. RESPONSES AFFECTING PURCHASING FUNCTION. A REVIEW

The belief, in many companies, that purchasing personnel should perform clerical tasks is fortunately progressively abandoned (Humphreys *et al.* 2000; Carr & Pearson 2002). To successfully face some of new mentioned challenges, people in purchasing function need to be deeply involved with company strategic goals and accordingly trained professionals, on a par with those in other areas of the company (Messner 1982). Business, interpersonal and technical skills must be present in the purchasing professional (Kolchin & Giunipero 1993), but more precisely training should focus on basic related topics such as environmental issues, *ad-hoc* legislations and regulatory controls, valuation, cultural differences, technical knowledge, the potency of the relationship between environmental programs and supplier selection, etc. (Murphy & Herberling 1994; Min & Galle 2001).

Needless to say, good tools back good results. Therefore, purchasing people need to be provided with information technologies, which help to streamline the handling of reverse

logistics products and supporting the ordering activities. Traditional tools for production planning and inventory control systems are impacted by the presence of returns. Although no much research has been devoted to examine the use and performance of MRP, OPT or JIT in recovery context (Wassweiler 1993), the current use of these techniques appears to require some adaptations to keep on being effective as a tool, among others, for planning orders. It seems not to be an agreement about how far should these modifications go, but their need is not questionable as special features characterize recovery context, not present in traditional scenarios, which affect directly to input information required for using these tools. Some of the complicating factors include highly variable processing times needed to perform required repair operations, probabilistic material substitution, highly uncertain nature of lead times for internally created inventories, etc. (Guide *et al.* 1997); master production schedule or data required for obtaining the explosion of materials needs fall within the area of influence of these factors. Examples of some attempts to give an answer in this vein are the studies of Panisset (1988), who discusses changes introduced in MRP II system to comply with specific issues in an Australian locomotive repair/refurbish industry, or Ferrer & Whybark (2001a) who propounds a material management system to determine, among others, how many and which cores to buy in the open market in an vehicle component remanufacturing facility.

Environmental qualification will be also required because, although steps to green purchasing practices are yet small, they are growing in number, above all, in some pioneer sectors such as, the automotive and electronics sector. Min & Galle (2001) already postulated big size companies to have bigger degree of involvement in green purchasing than their smaller counterparts. One indicator of this increasing in importance trend is found in the parallel mounting number of companies certified in environmental standards such as, ISO 14001, EMAS, etc. (da Cunha & Giacomucci 2002). Something similar happens in academia: environmental issues in purchasing are a relatively recent research topic but mounting in given attention.

Green purchasing[37] includes the acquisition of recycled content products, environmentally preferable products and services, bio-based products, energy- and water-efficient products, alternate fuel vehicles, and products using renewable energy[38].

Purchasing function may play a strategic role in approaching company position to a more environmentally friendly posture. In fact, the integration of environmental factors is usually taking place within traditional sourcing roles, namely, purchasing managers and quality assurance staff. The adoption, within procurement policies, of environmental tools such as, Life-Cycle Analysis (LCA) perspective allows, for instance, to look beyond purchase price. It also considers costs and environmental impacts over the lifetime of a product or service (manufacturing, packaging, transport, energy consumption, maintenance, disposal). A more precise estimation as regard real cost of a specific item should guide purchase decisions more wisely. Sometimes, a narrow perspective of the involved costs may give the wrong impression of a new component being cheaper than a recovered one; the same may happen with raw materials. A more thorough and ambitious view of costs along the whole life of the product may easily change the decision. Furthermore, LCA helps purchasing managers to reduce margins of error in forecasting future needs, as the stage of the product and consequently its probable condition is also considered. Other advantages of this approach may include a lower purchase price (e.g. material costs from suppliers also committed with environmental issues, remanufactured products).

"Firm's strong environmental commitment may reduce the pool of qualified suppliers due to stricter environmental quality standards" (Min & Galle 2001: 1223). Environmental stance is a new supplier selection factor and evaluation performance criterion. Only those suppliers with high environmental and quality standards in opposition to those whose products present high defect rate or not environmental friendly composition or design will not be dismissed.

---

[37] Also called "Affirmative Procurement," "Environmentally Preferable/responsible Purchasing," and "Environmental Purchasing"

[38] http://www.ofee.gov/gp/gp.htm

A step forward in the environmental commitment is the integration of suppliers into their customers environmental management process (Lamming & Hampson 1996; Walton, Handfield & Melnyk 1998) so that, some synergies could be reached. After screening suppliers for environmental performance, integration initiatives range from working collaboratively with them on green designs or helping them to build their environmental management capacity, etc. (Lippman 2002).

Integration with suppliers also takes place at product design level (Azzone & Noci 1998b). The design stage in the life cycle of a product may be critical for its posterior performance in the remaining stages. Before, these stages spanned "from cradle to grave". This expression has been currently substituted for "from cradle to reincarnation"; many OEM are already spurring their R&D departments to get products designed having reincarnation in mind. This includes environmental issues and the disassembly for remanufacturing, repairing or recycling. "Reverse logistics starts in the product development phase, where is important to consider which materials to use in production in order to minimize consumption of materials and the cost of a later separation and recycling of components" (Skjoett-Larsen 2000: 385).

Purchasing executives can play a key role in the design stage. Working together with the designer, they can positively influence the product's availability for remanufacturing or recycling by, for instant, selecting the most appropriate materials. The speed with which the company is able to quickly retrieve the parts and have them repaired may, in certain cases, represent months of supply that can be reduced. This reduces new buys and increases inventory turnover. Purchasing people have deep knowledge about materials properties and their availability in the market. Therefore, their judgement on materials is valuable. This is one example of how fluent communication between other departments of the company and purchasing department may render in improved overall performance.

From the design point of view, some outcomes have been a gradual shift to modularity and commonality in order to, among other objectives, mitigate the effects of uncertainty. Regarding modularity, one consequence to highlight on the purchasing side, is the increased trend for outsourcing more and more of the final product. On the other hand, higher levels of commonality make purchasing function easier. Several reasons contribute: first, commonality reduces the gamut of items to be supplied as, complexity in bill of materials decrease[39]; as a result, it reduces the need of information about a broad pool of suppliers; finally, it increases negotiation power as the required stocks of common parts increase.

One more aspect, as regards company relations with suppliers as a result of recovery activities, derives from reduction in the amount of new materials or components. The ability of the firm to efficiently reuse parts, modules or materials from the returns, offers savings in procurement of items that would otherwise have to be purchased. The straightforward implication is the shift from lesser dependency on external suppliers to bigger dependency on downstream supply chain members.

3.3.2.4. METHODOLOGY

For choosing the sample, some criteria were taken into consideration. First, if the influence of returns on purchasing patterns was objective of the research, companies should be necessarily involved in recovery activities. Companies selected carry out repairing and refurbishing tasks; recycling is also conducted in one of them. Second, key-purchasing managers should be approachable to get first hand information on their practices; companies were then selected having had some prior personal contact on our part with them. Third, size of the companies was thought to be a reliable indicator of their purchasing significance; therefore, big size companies were chosen.

[39] Rank-Xerox, for instance, has redesigned some parts in order to reduce the number of different plastics they contain; 17 different plastics formerly used in toner cartridges have been actually reduced to 6 nowadays (Ayres *et al.* 1997)

The utilization of several sources extends the possibilities of gathering a more comprehensive information and increases the possibility of obtaining a triangulation, which will give more compactness and robustness to the study. Taking it for granted, the following sources of data were used: some internal memorandums and articles in the mass media, direct observation and finally "*open-ended nature* interviews" with key persons, who no only answered the questions but collaborated in giving valuable information. Detailed data, concerning for instance costs, was not provided.

Interviewers manifested their concern about confidentiality and a commitment about not revealing the company name was made. Therefore, letters will substitute companies' identity: company A and company B.

3.3.2.5. PURCHASING IN THE COMPANIES ANALYSED

The cases chosen for the analysis are both local plants of bigger corporations characterized by the international scope of their businesses and their big size (size referred to both the number of employees in workforce and their turnover). Their position in the supply chain is in both cases manufacturer.

Company A

Its businesses are within electronics sector. Production is characterised by high mix and relatively low volume. As in any other company, objective is to keep inventory as low as possible and inventory turnover at satisfying level. Nowadays purchases follow JIT philosophy although inaccurate demand forecasts, market changes on component lead times and not always reliable information about inventory on hand, introduce some difficulties in JIT purchasing fulfilment. At the moment, even if electronics is one of the sectors in which

more environmental legislation has been passed and in spite the global scope of the company, the plant is not yet involved in the recovery of end-of-life products.

The only reverse logistics activities carried out are a consequence of damaged of faulty items. One of the following three options may apply depending on the extent of a damage: 1) the whole product has to be scrapped and a new unit manufactured, 2) part of the product has to be scrapped and some of the components or parts may be reused (cannibalisation) or, 3) product can be fixed by replacing some components (repairing, refurbishing).

The need for components, above all in the first case, can cause problems to purchasing personnel due to their unexpected need. In this situation, the degree of components standardization plays a critical role on lead-times: the more specific the component the greater the likelihood of a longer lead-time of a new purchase. Because the need must be satisfied in the right time, purchasing personnel have eventually to resort to the services of brokers, normally paying 2 to 5 times the price (fact also pointed out by Guide 2000). The lack of the required component may even halt the production line, which harmfully affects to the service level offered to the customer. In this situation, the possibility of procuring those components by means of an effective reverse logistics system combined with the disassembling of the recovered products could bring a remarkable not only lead-time reduction (Brennan, Gupta & Taleb 1994) but also acquisition cost reduction.

Usually parts that are worth disassembling for re-use purposes are box-building mechanics, cables and other valuable parts that are easy to disassemble. Component boards[50] are also good candidates due to large amount of different modules assembled in them, and therefore the value recovered. Electronics falls in the type of industry, Ayres *et al.* (1997) referred to when stated that if the models are changing rapidly, possibility of using recovered parts in new models is lesser. This occurs with boards: If revision D was the latest version at the time of manufacturing a certain component board, the latest version at the time of product return can be already E or F. The recovered component board cannot be reused in a product

[50] Printed circuit boards with components

assembly. Purchasing personnel need to keep trace of models technical description to decide if new purchases are then required.

Reverse policy with suppliers only applies with faulty or incorrect components that are returned to suppliers at their cost or, scrapped locally and credited by supplier. Company keeps record of these incidents as supplier evaluation relies partially on them. Suppliers' performance is measured regularly in order to have an update record of its trade relation history. Monthly ratings are based mainly on on-time delivery status and quality of incoming materials to prevent customer product rejections. Given that the company has included in its actual purchasing strategy the objective of reducing the number of suppliers, quality of the delivered components and service will heavily influence on final supplier selection. No backwards consideration is assessed. Foster co-operation with the final chosen suppliers is established in another section of the suppliers-related strategy.

The environmental management system is based on international standard ISO 14001. The company has integrated environmental issues into the quality assurance applied by the company to its suppliers. Key suppliers are informed about the environmental supplier requirements and they are also asked to provide a self-assessment of their operations in the light of these requirements. It also promotes suppliers to adopt the principles of its policy, and, where appropriate, requires improvements in their environmental practices and performance.

Most of the company units use Baan software system in material requirements planning, inventory and production control. Less consumption of new components, as a result of recovered stream, could translate into lesser burden in purchasing work. However, it is so only if the information of used components is transferred to the MRP system, and therefore, the resulting ordering planning is reliable enough. The disassembly and repairing staff not always communicate inventory variations; they may simply respectively put or take the parts to or from the warehouse, and in the worst case, not make any corrections to the

system. Even if, at the moment, reverse items play a quite small role, and the effect of neglecting inventory corrections is not crucial, not accurate information about on-hand inventory in the system can lead to obsolescence/shortage of components, since MRP generates purchase proposals based on it.

In summary, effects in purchasing patterns in this plant as a result of reverse logistics implementation are not substantial nowadays. The only observed changes derive from adhering to environmental standards. This is mainly, not because company had implemented a good system to handle with returns but because the amount is not yet significant and because managers seem not to be aware of returns potential; on the other hand, legislation does not push company performance in this direction. In spite of it, repairing of returned products was admitted to occasionally cause disturbance to the material supply for the production, not big enough though to give it more thought.

Company B

Company B is a local machine tools manufacturer plant that belongs to a big corporation, which operates in more than 100 countries and employs around 139,000 people. The machine tool could be useful for 30-50 years with reasonable maintenance. Some of its components are designed to have a long last live. However, since automation broke up in the 70's, capacity, technical or quality requirements become old-fashioned in a much sorter period.

Mainly to better meet customer requirements on the market, the company has chosen a modular product range strategy. Modularity according to Carliss, Baldwin & Clark (1997: 84) consists of "building complex product or process from smaller subsystems that can be designed independently yet function together as a whole". This strategy broadens the number of alternatives for customers to choose from. However it also facilitates the tasks of disassembly and recovery of old modules and retrofitting new modules to earlier delivered

machines after a new need appears (refurbishing). The trade-off when compared to serial production may be the cost-effectiveness, which can represent its Achilles' heel.

The company accepts the old machine as part of the contract and offers a replacement to customer, only if updating is not available at a competitive cost level. The old machine will usually be sent to the factory, where decision will be taken on repairing, remanufacturing, or cannibalising it. Recycling will be the last resort; apart from the control unit, the whole machine has been designed for being fully recyclable and purchasing personnel was consulted to know the availability of the required materials in the market.

Thus, modular strategy selection has resulted to serve at environmental and recovery aims too. The company, since first started 7 years ago, has implemented the ISO 14001 in 98% of the total number of plants affecting to 80% of the operations. Environmental concerns are slow but progressively sinking in the corporation (after 5 years, 2001 was the first in which a report on in-house recycling and reusing on its products and processes was made). Also suppliers, above all major suppliers of direct materials and services, i.e. those that go directly into manufacturing, are strongly encouraged to implement environmental management programs, in particular, ISO 14001; the company openly confesses to favour them. However, at the same time, the company recognizes that its role may be substantially improved and therefore, admits the need of benchmarking with more experienced companies in that field.

One of the biggest challenges for purchasing personnel regarding returns is strongly related to the long life of products. R&D department takes measures to ensure compatibility and substitutability between old machines and the most recent ones, which is critical for refurbishing the old machine. This demands from purchasing staff important endeavours to keep updated knowledge about the models, their components and suppliers for them. However, in certain cases, it may not be enough as some suppliers decide to give up production at a specific date with very short notice to react. The need for disposing of a

stock of these components force purchasing decision makers to either make a guess for a presumable amount of components (usually very expensive above all in high tech modules) or risking their business not being able to carry out refurbishing activities because of the lack of components.

3.3.2.6. CONCLUSIONS

To become fully involved in these recovery/reverse processes will in short time be, not longer an option to embrace but a compulsory issue to comply with for many manufacturers. The take-back scheme not only may not pose an additional burden on the company costs but also it may be self-supporting; even more, opportunities for savings and competitive advantages can be drawn whenever this process is efficiently run. Yet, for achieving both efficiency and increased value added, a full range of supply chain activities must be committed, purchasing being one of them.

The cases shown in this Section 3.3.2. are examples of the still scant degree of actual reverse logistics implementation in corporations. Apart from specific pioneers in some sectors (PC, printers, automotive) in which this practice has been more extensively adopted, reality appears to point out those to be more an exception than the rule.

Of the two cases presented, Company B seems to be in a more advanced position than Company A regarding the level of consciousness and implications of reverse logistics influence on the firm. The adoption of a modular design has eased the disassembly (activity unavoidable for any posterior recovery activity), and has reduced the times of transmitting information about recovered parts to the system, information required for the purchasing department when planning its materials orders and lead times. These cases empirically reinforce how modularity and standardization greatly contributes to better reverse logistics performance, seeming to be important design features to adopt. The explicit importance of design department in envisaging returns is strengthened by working in conjunction with

purchasing department (company B procedure responded more to this cross-functional integration than company A).

On the other hand, the degree of involvement in recovery activities is also superior as the company includes cannibalisation and recycling as alternative sources of respectively parts or materials that need not be purchased. The option of scrapping faulty products in company A prevents it from parts which have to later be not always easily sourced. Purchasing personnel are in this latter case subject to unnecessary, additional pressure.

Environmental certification seems to positively predispose firms to future progress in reverse logistics systems. Annual reports show an increasing commitment to environmental sustainability; this could be taken as a symptom of initial steps being given. On the purchasing side, one common effect is its translation into increased commitment with green purchasing practices (even if, according to Kitazawa & Sarkis (2000) the effect is not immediate unless cultural changes take place in the organization). A second effect is a more stringent evaluation criteria (because of added environmental requirements) to their suppliers. Environmental certifications by itself is however not enough for integration with suppliers to be fully achieved.

Finally, all abovementioned effects seem to respond more to external stimulus either from customers (when they return faulty products), or competitors (adoption of green practices). There is not an attitude to actively recover units (for instance, at the end on their lives). A major implication of this finding is that the importance high executives assign to reverse logistics issues as a means of reducing purchasing costs, increasing customer service, or reducing lead times is still very low. Neither systematical approach nor future projections seem to have been made.

3.3.3. TRACKING THE BOND BETWEEN ENVIRONMENTAL ISSUES AND REVERSE LOGISTICS. IS IT SO STRONG?

3.3.3.1. INTRODUCTION

Since the awareness for environment and sustainability boomed in the decade of 90's, the progress achieved in this sense has been noticeable. The statement is not arbitrary; apart from the number of companies certified in some environmental standards, already mentioned, some additional indicators firmly support it, such as, the great variety of ecolabels launched by manufactures in their products in order to show to the market their commitment with environmental matters; the growing utilization of the Life Cycle Analysis (LCA) approach as a basic tool for estimating the environmental impact of their products (Bloemhof, Nunen, Vroom & van der Linden 2001; Stavros *et al.* 2003), the adoption of green procurement as a new strategy for relationships with suppliers (Zsidisin & Siferd 2001; Drumwright 1994), etc.

This trend of increased responsibility with the environment has not been exempt from some resistances. Leaving aside the innovative companies, which adhered to the process from its inception, the rest reacted reluctantly at the beginning, as their impression was that the change would bring a raise in their costs. This initial resistant posture from some companies gave rise to a more resigned attitude mainly as a result of environmental acts and mandates passed (Walley & Whitehead 1994). Recently, regulatory compliance is increasingly being substituted by more proactive holistic approaches, having companies realized of the potential for resource efficiency and commercial opportunities.

The success of leading organizations in addressing green processes together with environmental legislation and customer demands have had as a result an effect of pulling some others, which were still unwilling to become involved. These latter firms have discovered that, not only the costs generated from going green can be (if efficiently managed) largely offset by benefits from the green image, but also they may obtain competitive edges (Winsemius & Guntram 1992). In addition to the previously mentioned

rewards, the fact of being involved in sociable responsible activities may, in a not far away future, constitutes a supplementary requirement for playing on in the market, and not an competitive advantage as it is still today.

The bond between the processes of going green and reverse logistics appeared to be inevitable. If 1) society, in general, demands a guarantee for environmental sustainability for the safety of future generations and if 2) legislation passed to that end a) stimulates/ obliges to reduce resources utilized in production processes and to protect landfills from actual and future wastes, and b) makes manufacturers responsible for their products, any recovery activity would be seminal to achieve those objectives (Krikke *et al.* 1999; Goldsby & Stank 2000). Reverse logistics could provide the logistics support needed for the value recovery to be a reachable goal (although other complementary tools may be also utilized such as Design for environment, or the Life Cycle Analysis). This link would be consistent with the assertion made by Porter & van der Linde (1995) according to which, as the environmental commitment goes further in a company, environmental decisions are not taken autonomously but tightly considering other decisions that affect other functional areas.

Numerous are the authors (Biddle 1993; Ayres *et al.* 1997; Maslennikova & Foley 2000) who so far, in their publications relate experiences of companies (generally leading companies) that have followed, for one or another reason, in a way or another, practices of reverse logistics as an additional ingredient in their strategies. However, from this statement to the one saying that the reverse logistics procedures have been adopted by a great majority of companies (Tan & Kumar 2003), there is a subtle difference.

Going deeper in this relationship between environmental issues and reverse logistics practices is the aim of the work presented in this section. We want to know if the reverse logistics field has, at the present time, the important magnitude that seems to be inferred from the most recent literature on the subject. Are companies implementing reverse logistics activities so extensively? Are they including them in the daily processes and

strategies? Do recovery activities play such an important role within the overall performance of companies so as, big developments in reverse logistics may be expected in the future? Are all the recovery activities equally significant for companies?

The remaining of this Section 3.3.3. is structured as follows. Next subsection aims at getting closer to the environmental and recovery situation of companies, narrowing the focus towards a specific industry; some hints are given about how these issues are adopted by the electric and electronics industry. Subsection three explains how the case study was accomplished. This is followed by the case study itself, carried out in a European leading company within this sector; its actual practices are disclosed. Ideas derived from the previous analysis are discussed in fifth subsection. Finally, some conclusions are drawn and future research areas are suggested in subsection sixth.

3.3.3.2. EXAMPLES IN PRACTICE. A GLANCE AT ONE SECTOR

In a number of countries is possible today to find initiatives whose aims lie in making aware of and fostering companies to turn towards environmental issues, so that these issues are internalised in their business thinking and strategies.

Although in the coming years every industry could expect to be involved, at the moment, only some are subject to the more stringent regulations with regard to the Extended Producer Responsibility[41]. These include automobiles, electrical and electronic equipment, packaging, tyres, batteries, plastics, etc. Leading companies in different industries, such as XEROX, IBM, Hewlett-Packard, 3M, Intel, Electrolux, Gillette, General Electric, AEG, Philips, Bosch, Sony, BMW, Volvo, General Motors, Nokia, AT&T, Coca-Cola, Kodak, Estèe Lauder and so forth, have been the focus of different studies because of their serious

[41] Principle according to which manufacturers and importers of products should bear a significant degree of responsibility for the environmental impacts of their products throughout the product life-cycle including impacts from the selection of materials, the production process and from the use and disposal of the products. (OECD 1997)

commitment in searching new processes and technologies, by means of which to reduce the environmental impact of their activities and products.

Since it was not the aim of this thesis to cover all the industries, the attention was focused for this piece of work in only one of them as an example. To that end, we have chosen one industry especially representative according to the two following criteria: first, environmental legislation has been passed, affecting directly to the products obtained, and secondly, the activity of the companies has a worldwide scope, what could guarantee its general comparison. Three types of industries satisfied these two requirements and therefore could be deemed as candidates for a closer analysis: automobile industry, packaging industry and electric and electronic industry (Fleischman *et al.* 2000). The remaining will concentrate on the latter.

The recovery of value in an industry such as the electric and electronic industry is not just a duty, but also a need, as stated by Hillegersberg *et al.* (2001), given the shortening of the life cycle of its products. Also Veerakamolmal & Gupta (2000) point out this need for recovery as they include the consumer electronic goods and household appliances among the products generating the bulk of the scrap along with cars and computers.

This necessity is reflected in what is still a proposal for a Directive on Waste Electrical and Electronic Equipment[42] (WEEE) and a proposal for a Directive on the restriction of the use of certain hazardous substances (ROHS) in electrical and electronic equipment. These proposals are designed to tackle the fast increasing waste stream of electrical and electronic equipment and complements European Union measures on landfill and incineration of waste. Producers will be responsible for taking back electrical and electronic equipment and complying with the recycling targets established for this kind of products, these targets ranging from 50 to 80%. Consumers will be stimulated to contribute to the process by

[42] Electric and electronic equipment is gathered around 10 categories: large and small household; IT & Telecommunications; consumer equipment (e.g. products that reproduce sound and image); lighting equipment; electrical and electronic tools; toys, leisure and sports equipment; medial devices; monitoring and control instruments; automatic dispensers.

being able to return their equipment free of charge. The role of the retailer is likely to be to assist in recovering electrical products from the consumer.

The proposed Directives have not been without controversy. For instance, some producers state that recycling targets of 50 % are unrealistic for most of the small electrical and electronic goods including electrical toothbrushes, coffee machines, mobile phones etc., which can include a variety of plastic types due to technical requirements. For these applications, energy recovery (after shredding and metal separation) would be the preferred option. In spite of this controversy, in 2002, mandatory electronics recovery laws were already in force in Belgium, Denmark, Italy, Netherlands, Norway, Sweden, Switzerland, Portugal, Japan and Taiwan. By 2007, 30 countries are expected to have enacted electronic recovery mandates.

Therefore the environmental issues are strongly linked with this industry. From this it could be inferred that companies operating in this industry will result deeply involved in adopting strategies to become environmentally friendly and in deploying the required reverse logistics practices so that the recovery and recycling legal targets are fulfilled in an efficient manner. The implementation of reverse logistics processes will take place whether in-house or outsourced to a third party logistic provider who, according to Meade & Sarkis (2002), seem to specifically be targeted to products and industries in which electronics and appliances are included.

Obviously, companies may face the need of customizing the implementation of recovery processes with other complementary policies, depending on what their situation is (Helms 2002). For instance, in the example provided by Meyer (1999), an electronic products manufacturer after realizing that half of the amount of products sent back by customers was not returned for being defective or end-of-life products[43] (returned products were actually in perfect conditions) decided to adopt a policy consisting of launching simpler product

[43] Similar high return percentage can be also found in a survey carried out among 65 consumer electronics manufacturers (RLEC, 1999); in this survey the 45,05% of the returns were because of defective reasons, whereas the remaining 54,95% belonged to the non-defective category.

manuals with which installation by customer was easier. Some other companies are allocating important resources in their R+D and product development departments, and notable efforts in improving their designs, in search of new approaches with which to achieve improved environmental performance along with commercial success. Several authors have addressed this issue (Johnson & Wang 1995; de Ron & Penev 1995; Gungor & Gupta 2002). Another means to avoid returns may be to use online helpdesks where customers are welcome to ask questions regarding any aspect of the installation process (de Brito *et al.* 2002); software pre-installation and easy-of-installation practices may constitute a via to be considered in personal computer and computer systems (Haug 1990; Cespedes 1995). Another possible strategy consists of developing and improving the information support needed by logistics managers in order to enhance visibility of products and forecast the required reverse logistics operations (Daugherty *et al.* 2002).

The following paragraphs gather some information related to recovery activities in electric and electronic industry found in literature.

A) Regarding repair, Fortuin & Martin (1999) state how in electronic customer products, replacement seems to be a more popular option for OEM than repairing. This is so, among others, because the difficulties in the service parts management, as the demand for parts is fully random.

B) As regards refurbishing, electronics is a technology that lends itself to comparatively easy upgrades (Goffin 1999; Rogers & Tibben-Lembke 1999). Actually, practices as DfD –design for disassembly- or DfE –design for environment- are not unusual as can be seen from the review made by Moyer & Gupta (1997). Hillegersberg *et al.* (2001:75) contend that refurbishing to upgrade a product to a specific but less-than new quality is offered by many electronic marketplaces. In a survey carried out by RLEC (1999), one fourth of the returned products went through remanufacturing in order to be resold in second markets. But, is _ of the amount a satisfying result?

C) Finally, as far as recycling is concerned, electric and electronic equipment, along with white and brown appliances, paper and glass is being collected in Netherlands, one of the earliest supporters of environmental legislation (although similar performance can be found in other countries across Europe), for the purpose of recycling (Lister & Dekker 2001). Recycling is also the option for the packaging materials utilized in consumer electronics. As far as packaging is concerned, probably the option of recycling is the better value recovery option, but is it so for electric and electronic products too? When the above-mentioned survey is recalled, recycling of returns products exceeds the remanufacturing option: 35.34% were recycled. Some electric and electronic products, such as computer or brown goods, contain precious materials (gold, platinum, palladium), which are recovered by the recycling process. However, they also contain highly demanded parts that could be reused in refurbishing or remanufacturing, even in cannibalising, producing by means of these three last options a bigger value added recovery.

Recycling is however the one that less recovered added value implies. With this in mind, it is easy to infer that if this option is the prevalent, society may not be optimising all the resources devoted to improve the environmental performance. This result has an obvious influence on the reverse logistics policy. The requirements to accomplish recycling are less demanding than those needed to fulfil refurbishing, remanufacturing or cannibalisation tasks. Suffice to think that avoiding these latter activities, companies get free from the thorny returns inventory control, diminish the scheduling complexity, etc.

3.3.3.3. METHODOLOGY

The analysis of reverse logistics implementation in Electcompa was conducted as a case study in order to disclose the ways the firm is using to handle and cope with this new challenge posed in the arena of the reverse logistics. The scope was limited to the reverse operations between two main customers (customer R and customer S) and Electcompa.

In order to reach reliability and to improve validity through triangulation several sources of information were consulted (multiple respondents within the organisation or multiple data collection methods). Yet, the bulk of the information gathered was obtained from interviewing four different people of Electcompa: two managers (Technology Manager and Quality manager) and two Products Specialists[44]. These four people were chosen for being the most directly related, in one way or another, to the reverse logistics in the company: Technology manager is the head of repairing services in the company; Quality manager is responsible for environmental issues; finally, Product specialists take care of the practical issues in the repairing and reverse logistics. Several appointments were arranged to successively, get the first impressions on the subject, check the information processing results, and give green light to the final document.

The manner interviews were conducted adopted the so-called "open-ended" nature, in which no specific list of questions was asked. Interviewer had previously prepared the meeting, writing down some key points to be discussed and not to be missed. However, a relaxing atmosphere and the chance of letting in, in the conversation, different views or facets from the people interviewed, were given priority.

Besides of interviews, a recent Bachelor's Thesis describing the return and repairing process for customer S was provided by the company after proper request, since it is a confidential document done for Electcompa. Annual reports were also handed over by the personnel of the company.

The company was promised anonymity; therefore a trivial name was chosen to refer to it: Electcompa. For similar reasons two main customers will be referred to as Customer R and Customer S.

[44] A product specialist is responsible for technical functionality of products assigned to him or her.

3.3.3.4. CASE STUDY: ELECTCOMPA

General Information

The parent company of Electcompa is one of the largest electronics manufacturing services companies and one of the leading companies in its field. The corporation focuses on communications technology products, providing design and manufacturing services together with after sales service support (after sales includes product analysis, repairing of the products, updating old products that are still in use, and logistic services). Customer's typology varies from product companies or brand owners to network operators or manufacturers of cellular networks; company clients may be found in any of the 12 countries comprised within three different continents.

Electcompa operates in Finland. It was established in 1998 when the corporation acquired a part of customer R businesses. Currently there are approximately 160 persons in the workforce in Electcompa. As Electcompa is a relatively small unit with restricted resources, the two production lines (PL1 and PL2) are forced to partially share some resources. However, both product lines have their own management and support functions, such as sales assistants and product specialists.

Electcompa was certified to ISO 14001 in 1998 gaining also ISO 9002:1994 certificate in the year 1999 and ISO 9001:2000 certificate in 2002. For efficient application of its environmental policy and its adaptation to local conditions, each corporation unit has its own, independent environmental management system (the group has articulated mechanisms to guarantee effective global coordination).

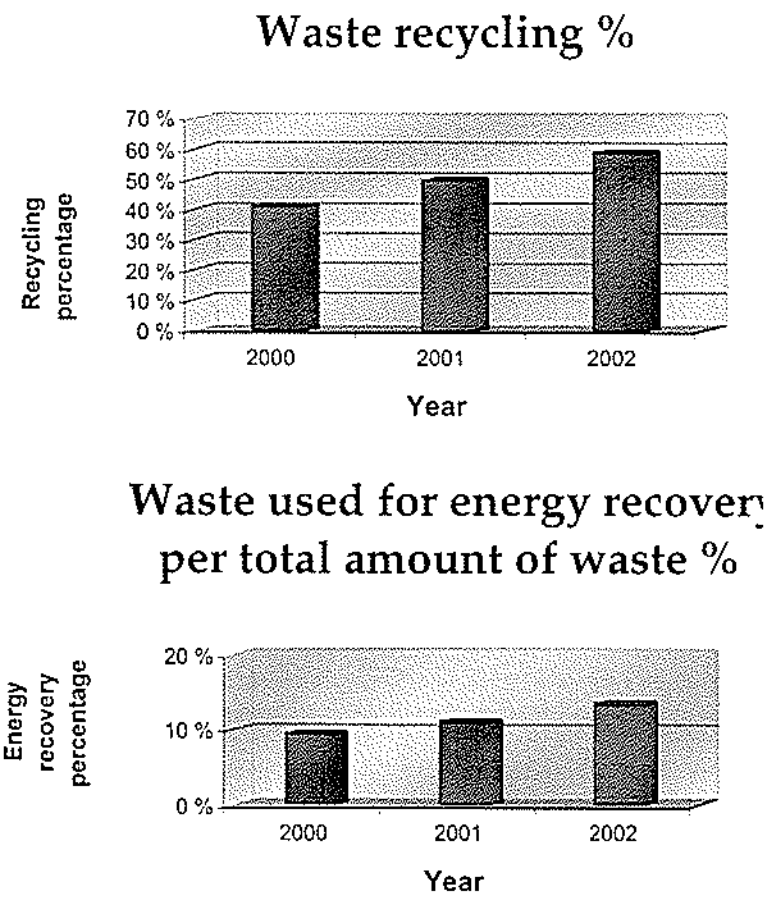


Figure 14. Two environmental parameters used by the corporation. Source: the web page of Electcompa.

Within its environmental commitment, the company is involved in several research and development projects aimed at, for instance, adopting a lead-free manufacturing process. The group monitors 25 environmental parameters on a quarterly basis. Some of them are shown in Figure 14[45]:

[45] How these indicators were translated for Electcompa was asked. However the records in the database seemed not to be valid (something that was evident when the technology manager tried to calculate different percentages of repaired and returned products). Had the charts been obtained from actual database, they would be very faulty.

Main Customers

Since the establishment of Electcompa, customer R has been its biggest customer, representing nearly 80% of the Electcompa sales (products sold are mainly relays and control systems). This main customer is at walking distance from Electcompa. Almost the whole production from production line, PL1, is assigned to this customer. As far as the second biggest customer is concerned, the second production line, PL2 (mainly heavy and quite large in a size modules), is mostly used for his products; since this customer, S, operates in several locations worldwide, products sold to him are shipped to several locations (from USA to China). Apart from two additional customers located in the same local area with Electcompa, the remaining customers are located further (for instance, in Sweden).

Forward logistics with the neighbour customer R is quite simple; most of the every day outbound logistics use post courier deliveries in metal or hard plastic carts. Modules sent to customer S use transportation in a freighter (waterway). Products to be shipped to Sweden are taken care of by chosen forwarder (transportation means are airfreight, in urgent cases, and trucks, in normal cases). When it comes to China and USA destinations, the forwarding can happen either on land, waterways or by air.

Although the amount of returned products from the two main customers is significant when compared to other customer's returns, reverse logistics is implemented in Electcompa in a quite limited scale. The percentage of returned products from customer R is estimated to be below 1% of the sold products. In spite of this, the importance of total returns (and thus the reverse logistics) is expected to grow due to two reasons:

- An increase in the manufactured volumes;
- Life cycle span; the expected life-time for the company products is normally longer than the time the company has been operating in the market; if the legislation and/or customer pressure demand to take end-of-life products back, this will start to happen in the years coming.

One of the reasons for such a reduced returns rate may be found in the high quality standards and controls. Most products are comprehensively tested before being sent to customers, what reduce to a minimum percentage the number of returns due to functional defaults. Quality controls are thoroughly performed (unless customer for some reason insists on an opposite procedure), the more so if customers are at a long distance because in those cases transportation is more complex and expensive. Among the products not submitted to test by Electcompa, the percentage of defective products is higher.

At the moment customers do not send end-of-life product to Electcompa to be recycled or appropriately disposed. Products go backwards, from consumers to Electcompa, mainly as a result of production defects or after sales service support. Depending on the condition, one of the following options will be taken:

a. to send the product to a disposal company, which assures appropriate disposition according to the legislation,
b. to obtain some components or parts for re-use purposes or
c. to fix it by replacing the damaged components.

The main, in volume, added value recovery activity carried out nowadays in-house in the company is the repairing activity. Repairing a functional defective unit is undertaken mainly for economical reasons (by fixing it, the company avoid the replacement by a new unit). However, certain degree of cannibalisation also takes place.

Reverse logistics and recovery activities with customer R

The short distance between the major customer, customer R, and Electcompa makes the communication and daily businesses relatively easy. Information flow is rapid also for the reason that most of employees of Electcompa used to work for customer R. Sometimes, if the customer R knows what the fault is and a order to his customers has to be filled, the product is fixed by customer R in his own premises; otherwise products are returned to be fixed in Electcompa. Urgency of a situation is the major parameter for determining the schedule of repairing operations. The product specialist defines this parameter trying to conciliate both customer's wishes and the workload of repairing staff. Once this urgency criteria is set, specific order for repairing each product is decided according to two other variables: customer importance, and particular fixing process characteristics. Finally, product specialist and technology manager organize repair activities. The repairing staff assigned to the whole company also performs products repairing activities.

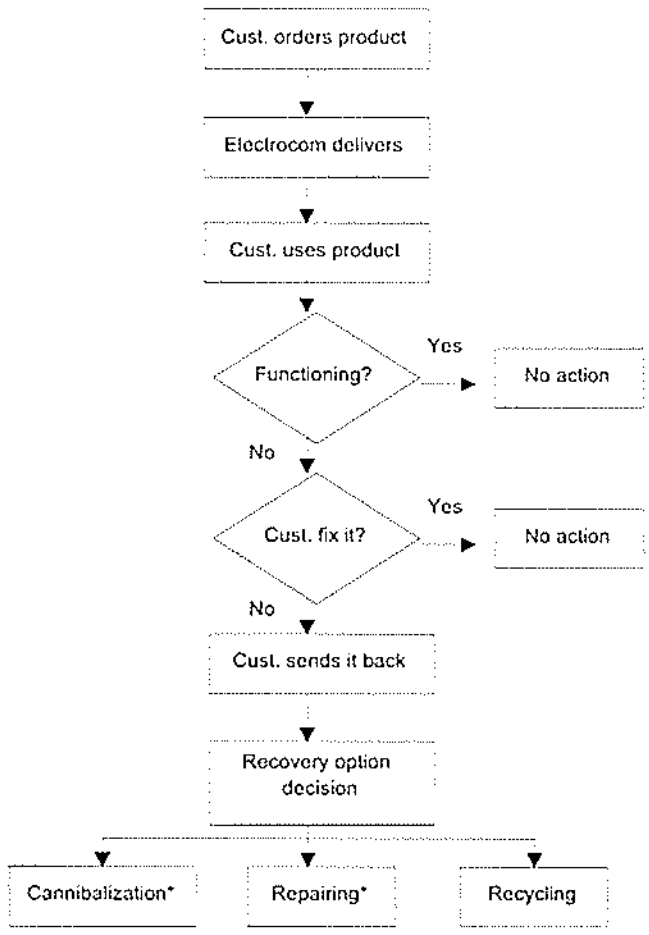


Figure 2. Return policy with customer R

Figure 15. Return policy with customer R.

The implementation, since September 2002, of Information technology to support flow information (formerly maintained in paper form) is expected to bring substantial improvement in the returning process. Actual records are saved into joint database kept by Electcompa and the customer. Both parties have author rights in the database what allows for very often updating. Old way of proceeding was to collect faulty products into large boxes and accumulated them at the customer premises to be returned at once. This procedure caused heavy sudden load for the repairing department, which had also to cope with its normal workload from internal processes. Nowadays defective returns are returned soon after the faults are discovered, as long as, customer R does not repair them by themselves or scrap them (these tasks usually accomplished when customer is responsible for the fault).

If the returned product cannot be fixed and it will be scrapped unless, as it happens very seldom, certain components can be advantageously obtained and reused again. According to one of the managers' believes "re-using electronic parts will never be an issue, although it may be for mechanic parts instead; in fact, mechanical components are the most re-used parts (within a limited extend) at the moment in Electcompa. The reasons why very rarely components are detached from the whole unit, are the required activities to do so, being time consuming (cleaning of the components can take a long time) and risky (if the components are not damaged while still on board, they can be damaged during the disassembly). On the other hand and in addition, the electronics components are not re-usable in a beneficial manner because intensive re-testing the parts is not worth; first, since most of the components on a board cost 0,00X € and retesting cost will far overcome the recovered cost; second, because more sophisticated components (the ones that will render big recovered added value) require specific tester (in other words, bigger investment in equipment). Therefore, some recovered expensive components cannot be tested before they are re-assembled to a printed circuit board (PCB). This means that there is a risk of being using a damaged component in the assembly of a new PCB since verification of its functionality was not possible. That is the case for example, with integrated circuits (ICs),

which are very difficult to test while not a part of component board; on the other hand, some memories that have been programmed for one unit cannot be programmed again. All these facts discourage the cannibalisation activity.

Only mechanics in box-built modules are re-usable, if not fatal damage occurs in transit or by customer. If the product is box-built, their components may be included in the top 10 of the most expensive parts.

Consequently, if a returned product from customer R has to be scrapped, usually the whole product will be scrapped. The general procedure for scrapping products is to put them in a locked[46] waste bin. The locked bin is transferred to a recycling company specialized in recovering metal constituents.

Defective returns from customer R come back to Electcompa in the empty carts in which new products were previously shipped. These carts come back (whether with faulty products or not), once the customer has emptied them (see Figure 14 for the whole decision making process).

Reverse logistics and recovery activities with customer S

The differences in reverse logistics policies utilized with customer S and customer R stem from several reasons, the distance and the dispersion of a number of the different customer locations being the most relevant ones. The distance between Electcompa and customer S is far longer than the distance between Electcompa and customer R. In addition, the products of customer S are shipped to multiple locations, which implies that they also come from multiple locations worldwide. The reverse logistics operations from customer S or customer S's customers are arranged and paid by customer S. The reverse logistics process implemented by customer S for returning modules and component boards is probably

[46] The reasons for the bin being locked are twofold: the material includes information that cannot be seen by outsiders (design, components, etc.) and the material is also so-called problem waste that cannot be disposed to a normal dump.

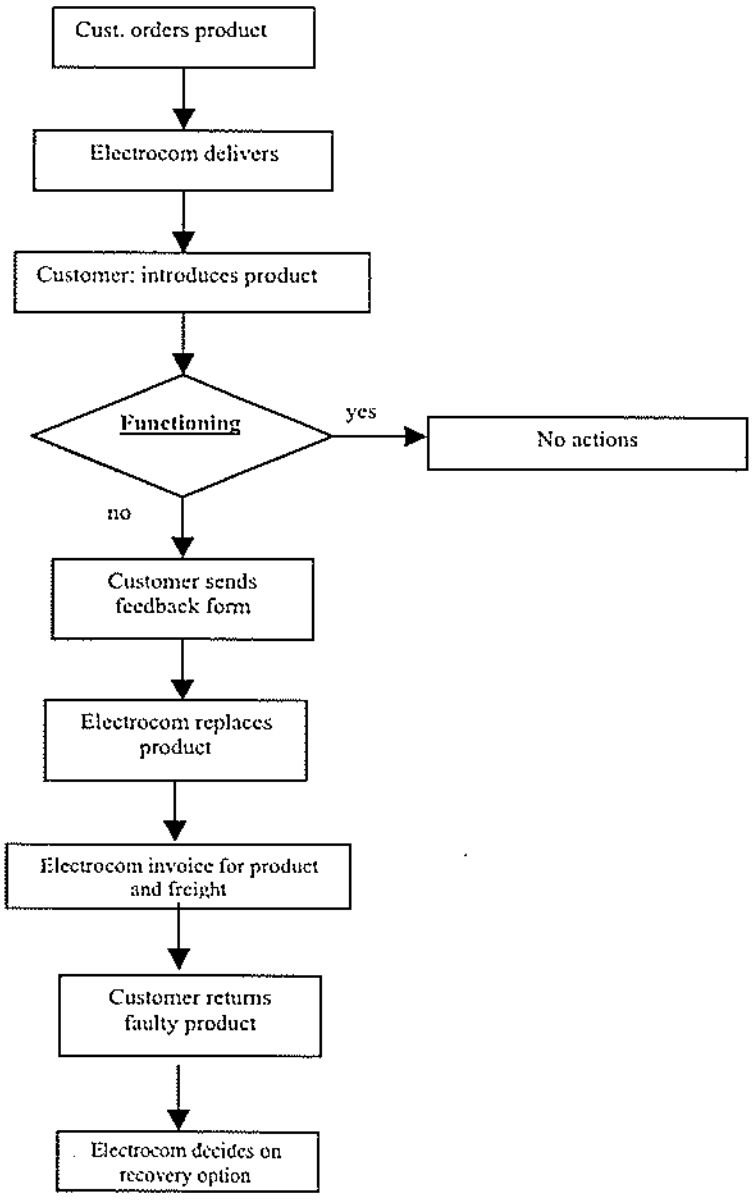


Figure 16. Return policy with customer S.

conducted, according one of the managers interviewed, in a much more organized manner since the longer distance translates into higher costs and since the volume of sales has recently increased.

Testing of the modules before sending them to customer in worldwide locations is also in this case fairly comprehensive, resulting in small percentage of returned products due to manufacturing faults. Customer S owns the test equipment and it is therefore his responsibility to provide rightly functioning testing equipment.

The procedure is more complex than with customer R (see Figure 16): customer S sends a feedback form reporting the defect to Electcompa. This feedback form is an electrical document that includes all the necessary technical information of the faulty product and the quantity so that Electcompa can send a replacing unit to the customer.

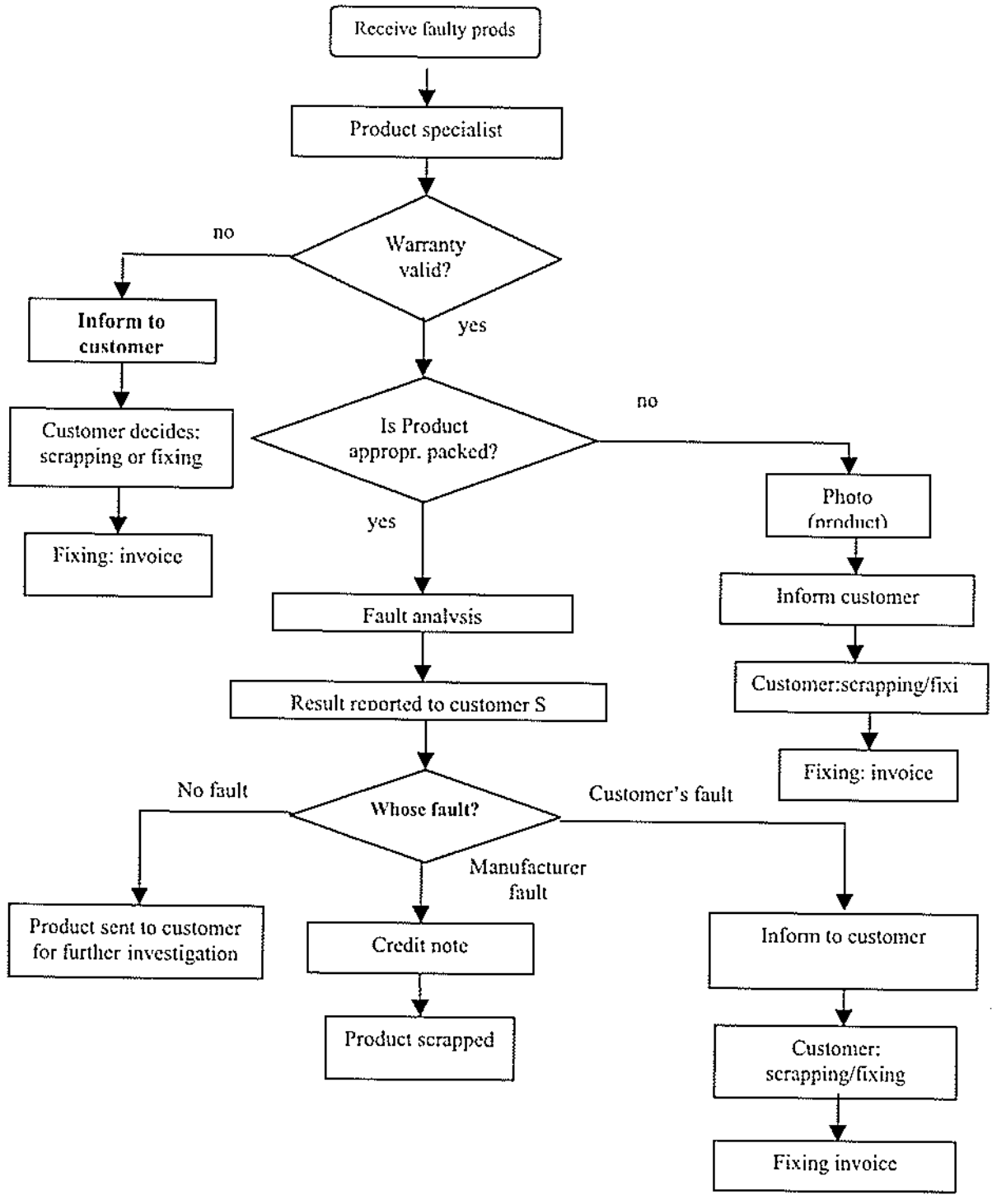


Figure 17. Internal decision-making process with products from customer S.

Depending on the customer S's wish the replacing module/part is delivered directly to the location where it will be used (customer's customer, end user of the product) or to customer S. Electcompa also sends an invoice for the product and its freight to customer. Once the replacement unit is in the appointed destination, the faulty product is returned to Electcompa. The return transfer is at customer S expenses. One in Electcompa premises, the procedure is similar to the one explained for customer R.

Faulty product is either credited to customer or property of Electcompa without liabilities, depending whether the warranty is in force and on who is responsible for the defects. Quite often, end users (customers of customer S) have caused the damage through incorrect assembly or incorrect handling. If the module is property of Electcompa, the option of reusing some parts will be analysed. Figure 17 shows the internal decision-making process with products from customer S.

The problem encountered often is that versions of some of the component boards change quite frequently and therefore they cannot be used for remanufacturing new products. On the, other hand updating used ones may be feasible but at cost too high.

3.3.3.5. DISCUSSION

From the previous case study some propositions can be drawn.

Proposition 1 is stated as follows: *physical distance between directly connected members in the supply chain has a crucial influence on the integration of Forward Logistics with Reverse logistics: the lesser the distance the greater the likelihood of integration.*

The fact of customer R being located at a walking distance from its manufacturer facilities facilitates the incorporation of returned product in daily practices in a remarkable way. Carts used for transporting new manufactured products are used, once empty, in their way

back to bring defective returns. Returns from R to Electcompa seem to coexist on daily basis with forward flows, leading to the integration of both processes (forward and reverse). When focusing on the faraway customer S, the return policy is quite different and more intricate in the sense that several steps have to be covered: filling of the form and the subsequent replacement of the faulty unit need to be accomplished to have the defective product back to Electcompa. Reverse logistics process is, in this second case, completely independent of the forward flows.

Proposition 2 is formulated as follows: *short physical distance between directly connected members in the supply chain increases the speed of returns transactions.*

Defective product returns from customer R are sent backwards to Electcompa as soon as the faulty product is detected. Not only physical flows but also the related information is available quicker. Costs considerations make more likely the utilization of economic inventory policies when distances to cover are significant. In such a case, transportation and eventually warehousing costs may deter companies from expediting individual units.

Proposition 3 contends the following: *the number of locations from where returns are sent back to the manufacturer is positively correlated with the required Reverse logistics resources.*

While customer R shipped defective products from a sole location using carts for transporting them back to Electcompa, customer S, with multiple locations worldwide, needs to resort to an increased variety of transport means to handle with returns. The latter is also likely to imply different kind of service contracts and relationships with different 3PL's. For the same reason, not only reverse logistics processes but also the subsequent redistribution processes will be more intricate.

Proposition 4 is stated as follow: *Characteristics of the product strongly affect the reverse logistics channel configuration.*

Characteristics of products have also a remarkable influence on the choice of the recovery option, making individual decision not possible to be extrapolated from one category to another. White, Masanet, Rosen & Beckman (2003) give prove of it when computer market is compared to other durable good markets. In the case analysed size and weight of products notably constraint the way products are transported.

Proposition 5 is stated as follow: *Scant returns volumes may favour the preference for one recovery alternative (more specifically, recycling) against other alternative options.*

The case analysed in previous section fall under the characterization of a low return volume company (only 1% from the biggest customer); therefore, Electcompa is not urged to react to the need of accommodating its procedures in order to cope with big flows of returns. Repairing is conducted as a traditional customer support service. Leaving aside this option, recycling represent the biggest recovery action. Some cannibalisation was carried out very seldom both for technical and costs reasons; on the other hand, the number of re-usable parts does not reduce material-purchasing costs significantly. In a survey of 65 major electronic and electrical manufacturing American companies, an average returns rate of 8.46% was reported (RLEC 1999). The costs of designing and putting in motion the required reverse channel together with the costs of planning and organizing the subsequent activities, may not be offset by the flow size needed to pay it off. Bellman & Kahre (2000) recognizes that industries such as electronic product industry may not generate enough volumes. In this vein, Mason (2002) mention the case of 3M, company that manufactures, among other products, electronics telecommunications; this company has been accepting products manufactured by competitors in order to reach volume. The marketing director of one of the technical services, exclusive of important mobile phones manufacturers in Spain, admits the challenge of the business to be in reaching volume; to get scale economies is essential (Schell 2003).

Proposition 6 is formulated as follows: *Without appropriate DfD, Complex product returns may discourage implementation of reverse logistics practices with focus on refurbishing, remanufacturing and cannibalisation, favouring recycling instead.*

Bellman & Kahre (2002) includes the electro-technical goods (domestic electronics, appliances, measuring instruments) as examples of complex products, in the sense that various and different components and materials take part in their composition. In the survey conducted by Armistead & Clark (1992), these authors found that, on one hand and, as far as customer support of complex products is concerned, this type of goods require a bigger support; on the other hand, manufacturers, in general terms, want logically exert a maximum control which is achieved by organizing a direct customer support channel. However, it should keep in mind that this type of control implies higher costs, what may be deterrent for certain companies. As complex products cannot be disassembled and recovered by companies without the appropriate know-how, if the manufacturer refuse to directly take part in the recovery, other companies cannot do anything but shredding them and try to obtained the precious materials they may contained. The cases showed how the phase of disassembly implied the risk of destructing the product, discouraging the recovery of parts. If no special resources on Design for Environmental (or Design for Disassembly) are allocated, the activities of refurbishing, remanufacturing and cannibalisation may not be economically affordable, being once more, the activity of recycling the next in the list, in order to comply with legislation without badly affecting the revenues of the company.

Proposition 7 contends the following: *The life cycle of electric and electronic products has influence on the choice of recovery activity utilized and therefore on the reverse logistics solution implemented.*

Especially in this kind of products, both market cycle and technological cycles have amazingly been reduced in the last decades. If the possibilities of technologically updating them would have been taken into consideration in the early stages of product development, the option of refurbishing the returned product could result viable. Otherwise, as it happens

in the analysed case study, product may result damaged in the disassembly process, leading to refurbishing not being the best solution. On the other hand and as regards remanufacturing or cannibalising, it may also happen that when the product is sent back, only a fraction of its components are eligible for remanufacturing because the short life cycle made obsolete the majority of its components.

These propositions answer the questions posed in the introduction section. Reverse logistics, in general terms, are not yet fully internalised within companies' strategies and procedures. Only under certain circumstances, returns management is a part of natural every day activities. Apart from the prominent role that recycling seems to play when it comes to returns, repairing is also carried out; however, more for after-sales service support reasons than for recovering value and /or environmental reasons. The remaining recovery options seem to have a low profile.

3.3.3.6. CONCLUSIONS AND FUTURE RESEARCH

Even if Electcompa is a part of a big corporation in which the involvement in environmental issues seems to be taken quite seriously, the implementation of reverse logistics practices still remains at very low levels. The bond between both processes (going green and reverse logistics) is not yet fully consolidated. The main recovery activities carried out by the company fall under the traditional scope of after-sales customer service (repair) or recycling, being the remaining options undertaken very seldom.

The environmental certification of the company shows a certain commitment with green issues. However, the fact of being certified appears not to be enough guarantee (Fernández 2003b) for the company to accomplish, in a deeper way, value recovery activities or to devote resources to deploy the required structure to support them. One question that arises at this point is the responsibility of public institutions for this outcome. Usually, legislation mainly establishes recycling targets, although in certain cases, recovery targets are also

mentioned[47]. Is it possible that these legal terms induce companies only (or mainly) towards recycling focus? May the companies get the impression (at least, those legislation-driven) that by complying with the recycling targets, not further efforts in alternative value recovery options are required?

Legislation has proved to be a powerful driver for companies to get involved with environmental concerns. If customer requirements (another potent driver) are considered when deciding how deep to green the company, costs of doing so may curb certain companies' initiatives. Legislation however may impose actions to be taken even if they are costly. In spite of it, it seems, broadly speaking, that compulsory terms are not sufficient enough to succeed in engaging companies further than mandatory terms establish[48]. Alternative means should be studied.

This case study also showed how the same company has set different reverse logistics procedures for different customers according mainly to two parameters: distance to customer location and number of customer locations.

3.4. TOWARDS REVERSE LOGISTICS THEORY BUILDING BY MEANS OF AHP APPROACH

This section presents a AHP study based on the state-of-the-art review along with the results obtained from the exploratory case studies introduced in previous sections.

---

[47] Let us take the packaging legislation (Cairncross, 1992):

Germany	According to packaging ordinance passed in 1991, 80% of all packaging must be collected and of that, 90% of glass, tin and aluminum and 80% of other packaging must be separated and recycled.
Italy	Has set recycling targets of 50% for glass and metal drink containers and 40% for plastic to be meet in 1993
Austria	Has set targets for recuperation –refilling or recycling- of up to 90% of drink containers by 1994
France	A committee of the 20 largest packagers, retailers and manufacturers suggested to recycle, refill, compost or incinerate with energy recovery _ of all packaging waste

[48] One of the managers pointed out that Electcompa has been functioning only for some five years. For him this could be one of the reasons why Reverse Logistics was not implemented in a greater extent. The idea behind was that during this time the company's main concerns were others: forward logistics, quality, compliance with environmental legislation, etc, tasks which the company deems as more critical.

3.4.1. INTRODUCTION

To succeed, corporations need to respond to external and internal changes in a timely and effective manner (Wu & Dunn 1994; Montgomery *et al.* 2002). Because Logistics acts as a critical interface along the supply chain, connecting its different echelon members, it may be effectively utilized to respond to the new challenges posed by markets and times. Within the logistics organization, the improvement of the quality of the logistics chain seems to be the main concern, regardless the length of the planning horizon (Korpela & Tuominen 1996). One recent way of achieving this goal is to broaden logistics scope by effectively undertaking reverse logistics activities and by incorporating the natural environment into strategic and operational decisions (Thierry *et al.* 1995; Sarkis 2003). Slowly but gradually managers and policy makers are realizing that good reverse logistics practices can positively influence on corporate performance. Benefits such as the development of a sustainable business strategy, improvement of customer service, increase of profitability, reduction of cycle times, and a cut down in purchasing costs, are already mentioned in the literature (Schary 1992; Kearney 1994; Dawe 1995; Phelan 1996; Dowlatshahi 2000; Hillegersberg *et al.* 2001) and in this work.

If, according to Lambert & Cooper (2000: 65.), "there is a need for building theory and developing normative methods for successful Supply Chain Management practice", this fully applies to reverse logistics, field where little prior theory exists which could serve as a framework for decision-making. Carter & Ellram (1998) pointed out the lack of theoretically grounded and holistic view of reverse logistics. Dowlatshahi (2000) acknowledged this same deficit. Knemeyer *et al.* (2002) missed an in-depth understanding of the complexity of factors affecting the reverse logistics activities but they only addressed the problem for EOL computers. Mason (2002) notes little demand of knowledge in this field. Issues like:

- What is the real implementation of these practices in companies,
- What are the most common decisions regarding reverse logistics channel configuration,

- Under which circumstances in-house implementation results in a more strategic solution than outsourcing,
- Which is the extent of the problems that hinder backwards activities adoption,
- Which of the external pressures is more credited by organizations,
- What are the factors that favour the integration of forward logistics with reverse logistics chains,
- How corporate environmental commitment affects the reverse logistics put in motion process,

are only examples of questions that have arisen without not yet a clear answer.

This study focuses on the challenge of drawing a deeper insight on the topic, with which future reverse logistics theory could be further developed. To do so and bringing together conclusions drawn from previous literature and the case analysis put forward in previous sections, we propose the use of the Analytic Hierarchy Process (AHP) as a tool for screening and assessing the relative importance of various detected traits.

For over nearly 30 years since the publication of the first papers, individuals with different background (scholars, managers, governments) have used AHP as a support tool for analysis, synthesis and justification of complex decisions and evaluations (Wasil & Golden 2003). Its versatility has already covered a wide range of application areas including supplier evaluation, production and operations management, formulating marketing strategy, human resource management, product pricing decisions, etc. In spite of some criticisms (Dyer 1990; Schoner & Wedley 1989; Schenkerman 1997; Barzilai 2000), AHP approach is still very frequently used nowadays. However, AHP has not yet been extensively used in the area of reverse logistics.

The remaining of the Section 3.4 is structured as follows. In subsection 3.4.2, we briefly summarize the key attributes of reverse logistics later considered in the AHP analysis. Subsection 3.4.3 describes how the AHP approach was delineated for this work. Subsection

3.4.4 presents the results. Finally, in subsection 3.4.5 some concluding remarks are addressed along with suggestions for further research.

3.4.2. SUMMARY OF THE MAIN REVERSE LOGISTICS ATTRIBUTES

A holistic analysis of the effective implementation of reverse logistics systems should consider both external and internal factors (or actors) with power to shape the process (Carter & Ellram 1998; Knemeyer *et al.* 2001). External actors include: government and interested groups, which may exert influence on regulatory bodies (lobbyists, consultants, etc), customers, suppliers and competitors (among those competitors retailers, recyclers, and competing companies may be found). Among the objectives pursued by these four actors the following can be mentioned:

a) reduction of generated waste (Dowlatshahi 2000),
b) better utilization of resources –labour, raw materials, energy (Ferrer & Ayres 2000a) at national level,
c) environmental protection (Stock 1998),
d) reduction of areas of disposal (Knemeyer *et al.* 2001),
e) reduction in prices while maintaining the quality level (Knemeyer *et al.* 2001),
f) extension of life cycles of products, and
g) increase the market share.

Internal actors have to do with the companies themselves. The reverse logistics-related objectives behind companies' practices may be also split in two different categories: strategic and operational (Dowlatshahi 2000). Among the strategic objectives, several authors (Stock 1992; Giuntini & Andel 1995; Witt 1995; Wu & Dunn 1995; Phelan 1996; Maslennikova & Foley 2000; Hillegersberg *et al.* 2001) have pointed out the ones summarily listed as:

a) Increase the offered customer service, thus, customer satisfaction and consequently, improve the company image in the market;
b) Augment profitability;
c) Reduce strategic costs -specific equipment, qualified employees, and warehouse facilities among others-;
d) Shrink cycle times;
e) Incorporate environmental concerns into business strategy;
f) Comply with ad-hoc legislation;
g) Keep quality standards;
h) Keep control, etc..

Operational goals (Murphy 1986; Kopicki *et al.* 1993; Andel 1995; Ayres *et al.* 1997; Stock 1998; Lieb & Randall 1999) are related to:
a) Transportation – truck, rail, routing, etc. -, which usually represents the largest reverse logistics costs;
b) Warehousing –private or 3PL; size, etc.- and
c) Supply management.

It is easy to realize/comprehend that some of the objectives previously mentioned may be in conflict and therefore, the effective power of each of the four forces will translate into different reverse logistics outcomes. So far, any analysis has made an attempt to measure the relative influence of these four factors as far as reverse logistics issues are concerned.

Nevertheless, although some conflicts may arise among the objectives targeted by different actors (Handfield *et al.* 1997; Majumder & Groenevelt 2001), the overall aim should be that the benefits from an effective reverse logistics implementation would be complimentary; for instance, extending product's normal life cycles leads to reduction in the needs for new resources utilization (Melbin 1995) which favours simultaneously both the companies and the environment; other examples of benefits for multiple actors may be found in Biddle 1993; Ayres *et al*, 1997; Blumberg 1999; Savaskan 1999 or Bowen *et al.* 2001.

Recovery activities may be highly profitable –which does not imply that then it would be in any situation (Klausner & Hendrickson 2000). However it may be long before an organization deals effectively with reverse logistics (Dowlatshahi 2000). The reason behind this argument is that the accomplishment of previous objectives by implementing reverse logistics practices is not exempt from problems, from both within and outside the company (Tan & Kumar 2003). Some of them, pinpointed in our state-of-the-art review and previous work, are the following:

1) Distance from customers: (Fernández & Korpilähde 2003; Tan & Kumar 2003);
2) Number of customer locations (Fernández & Korpilähde 2003);
3) Characteristics of the product -size, weight, cost of its components, etc.- (de Brito *et al.* 2002);
4) Complexity of the product -number of constituent parts, degree of modularity, degree of standardization of its components, etc.- (Ayres *et al.* 1997; Fernández 2003b);
5) Scant volumes, difficulties to reach economies of scale: (Stock 1998; Pohlen & Farris 1992);
6) Lack of knowledge of company's customers: (Ayres *et al.* 1997; Blumberg 1999; Fernández & Junquera 2003);
7) Uncertainty: the difficulties in forecasting quantity, quality, location and timing of returned products is doubtless one of the most-accepted characteristic of reverse logistics systems (Ayres *et al.* 1997; Guide *et al.* 2000; Hillegersberg 2001; Ferrer & Whybark 2001a; Fleischmann *et al.*, 2001; Guide & Wassenhove 2001; Mason 2002; Fernández & Junquera 2003); although some efforts have been made in providing tools with which to increase the accuracy of forecasts (Krupp 1992), and suggestions have been given to "attempt to secure input streams" (Knemeyer *et al.* 2002), uncertainty is still a hard point in effective reverse logistics implementation;
8) Lack of managerial commitment: the number of products ending in landfills would drastically diminish if companies were familiar with the social and economical advantages that could be drawn from recovering value or materials from them; however, it is a fact that many managers have discarded this business area (Thierry *et*

al. 1995; Rogers & Tibben-Lembke 1999; Meyer 1999; Goldsby & Closs 2000; Walker 2000; Stock 2001; Fernández 2003b);

9) Lack of design for environment, for disassembly, for recycling, etc.;
10) Costs related to high value recovery option. Knemeyer (2001) found that "skills required by employees and storage space requirements made strategic costs to increase dramatically as the focus shifts from recycling to refurbishing";
11) Existence of markets for reprocessed products (Biddle 1993; Thierry *et al.* 1995); although Purohit (1992) asserts that "any product category in which technology changes rapidly or consumers turn products over before they wear out suggest the existence of a secondary markets", examples can be found where recovery systems have failed because remanufactured products could not be sent to market destinations; although greening procedures are often linked to reverse logistics procedures, the fact of having verified an increase in the demand of green products which is not parallel to the increase in reprocessed products, shows that both processes are not equivalent;
12) Scarcity of developed cost information systems (Mason 2002) with which to get insight on both the costs generated from the reverse logistics activities and the cots savings stemmed for performing those activities (as an example, in the case study presented by Handfield (1997), none of the five companies analysed had a cost system implemented);
13) Lack of performance measurement systems; in the literature reviewed only two attempts are mentioned: Distribution overhead (Tan & Kumar 2003) and Return to available (Lambert & Cooper 2000);
14) some myths or misconceptions, such as, thinking that reprocessed products and lower quality are coupled (Biddle 1993) or that costs related to reverse logistics activities are comparatively much higher that traditional ones (Sarkis *et al.* 1995; Min & Galle 1997).

Because, as already mentioned, to become involved in the reverse processes will be shortly a compulsory issue to comply with for many corporations, companies are faced with the challenge to effectively adopt an important series of decisions. Probably one of the first ones consists of deciding which recovery option to perform. Some options (i.e. direct reuse, repair, refurbishing or remanufacturing) extend the product life span, whereas others (such

as cannibalisation or recycling) allow an enlargement of the material life cycle (Thierry *et al.* 1995; Ferrer & Whybark 2001b). Each option demands a deployment of logistics infrastructure and means with peculiar characteristics (Ammons *et al 1997).*

Once the recovery option has been determined, the subsequent decision would be on whether if the required activities are more conveniently carried out in-house or, on the contrary, they are better left to third party logistics providers.

At this level of the decision-making process, another question that arises is related to the design of the network that will support the return flows along the chain (Fleischman *et al.* 1997): should it be integrated with the forward logistics chain? Or, given the special characteristics of the reverse logistics activities (Guide *et al.* 2000), should an independent channel be used (Ginter & Starling 1978)?

The content of this section has been gathered in the Figure18.

3.4.3. AHP

3.4.3.1. ABOUT THE METHODOLOGY

The AHP is a multi-attribute modelling methodology first introduced by Saaty (1980). Although other multicriteria approaches (ELECTRE[49], MACBETH[50], MAUT[51], SAW[52], TOPSIS[53], among others) could have been considered, the fact that some papers (Zanakis, Solomon, Wishart & Dublish 1998; Salomon & Montevechi 2001) had shown the goodness of AHP method over the alternative methods and the fact that thousands of previous AHP applications have been successful, drove us to conduct the analysis with AHP.

[49] Elimination and Choice Translating Reality (for more details see Benayoun, Roy & Sussman 1966)
[50] Measuring Attractiveness by a Categorical Based Evaluation Technique (for more details see Bana e Costa & Vansnick 1994)
[51] Multi-Attribute Utility Theory
[52] Simple Additive Weighting
[53] Technique for Order Preference by Similarity to Ideal Solution (for more details see Hwang & Yoon 1981)

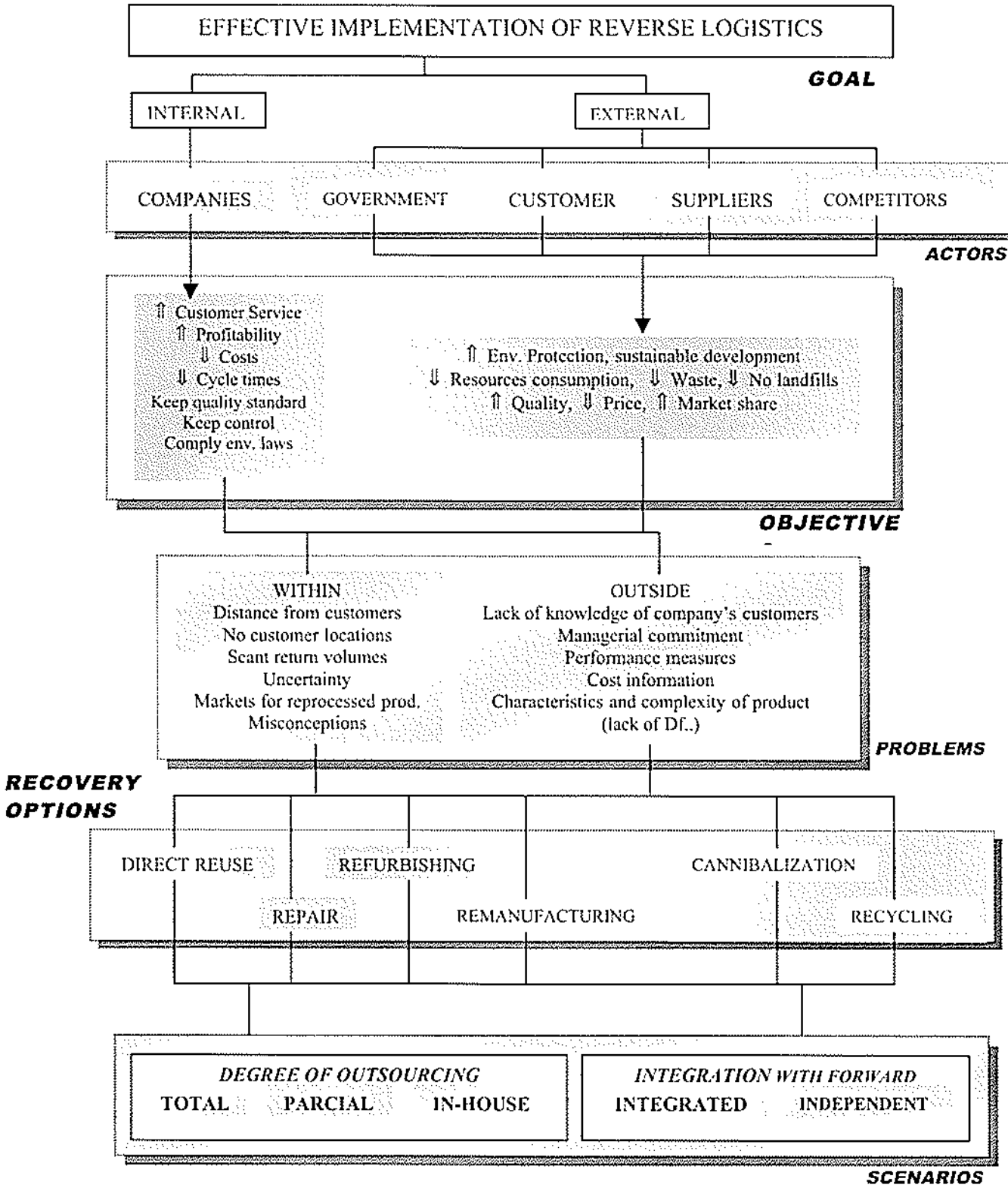


Figure 18. Framework for reverse logistics attributes used in AHP model.

On the other hand, AHP is one of the most adequate tools to transform the impressions drawn from the case studies into arguments upon which future decisions can be made. This is possible because the subjective impressions can be quantified and processed in an objective fashion. Therefore, the methodology fitted within our purposes.

The analytic hierarchy process consists of:

- first, structuring the problem information (usually in a decision tree form, so that, a hierarchy is obtained);
- secondly, establishing priorities among the elements of the hierarchy; to do that, judgements from a group of expert members are usually collected by means of a tailor-made questionnaire and translated into the form of relative measurements with a ratio scale;
- third, checking the consistency of these judgments; finally, aggregating those priorities, which result from consistent judgements to yield a set of overall priorities.

3.4.3.2. ABOUT THE APPLICATION IN THIS CASE

The questionnaire was developed from the key insights drawn from previous research work. In order to limit the sample more precisely, coupled with keeping in line with previous studies, attention was focused on two echelons of the supply chain: finished product manufacturers and part suppliers. Gathering information from different sectors and from companies operating in different markets (since some are end consumers oriented whereas others are selling to manufacturers) were relevant factors so as to expect the decision patterns to be significantly different.

The questionnaire was first mailed to 86 companies (in AHP matrix format) and sent to another 86 by normal post (in traditional question format). Whenever possible, the targeted respondents were the logistics managers and/or after sales managers. The composition of

the respondents sample bearing in mind the position of the respondents' companies within the supply chain, is reflected in the Figure19[54]:

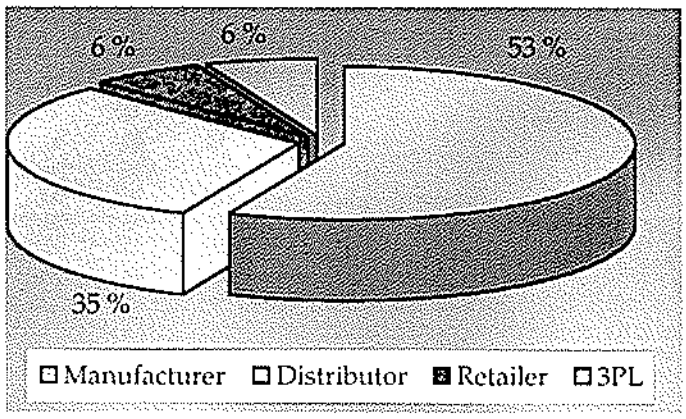


Figure 19. Composition of the sample.

Due to the fact that no connection between companies was assumed, the respondents were treated as independent entities and therefore, their individual judgements were aggregated using the method called "aggregation of individual priorities", AIP (Forman & Peniwati 1998). Individual priorities were obtained by means of the eigenvector associated with the maximum eigenvalue of each matrix; the components of the eigenvector represent the weights (or priorities) of the alternatives contain in the matrix. Matlab 6.5 was used to carry out these calculations. Although in AIP context both arithmetic and geometric mean are meaningful, Saaty (1989) suggests using the latter[55].

3.4.4. RESULTS AND DISCUSSION

From a sample of 192 (Statistical Yearbook of Finland 2002), we were pleased at receiving 16 questionnaires. Nevertheless, only a number of 90 companies would have permitted to

[54] Although the focus of the study was on manufacturers, some of them resulted to also play a second role.
[55] In such a case and having n individuals, the geometric mean will be obtained as the nth root of the product of the n individual priorities.

extend the results to the total population of 1467 Finnish manufacturing companies[56]. Being not the case, conclusions must be taken as suggestions for future studies.

One of the drawbacks in practice of the AHP application is that respondents should demonstrate thorough attention to keep some degree of consistency in their answers by remembering previous comparison values. In the study, a rather high percentage of the responses had to be dismissed due to the high inconsistency ratio. The influence of the number of comparisons to be made in each block on the inconsistency was statistically tested; the aim was to examine if the questionnaire design could have affected to the level of inconsistency obtained. The null-hypothesis, H_o, was that there is no difference between the percentages of unacceptable responses obtained from each of two blocks [H_0: $p_i - p_j = 0$]. Based on the 95% confidence interval, we found that null-hypothesis could not be rejected[57] (as the 0 is comprised in all the intervals[58] as is shown in table 6).

Table 7. 95% Confidence Intervals.

	Block b	Block c	Block d
Block a	[-0,137; 0,537]	[-0,201; 0,467]	[-0,260; 0,394]
Block b		[-0,421; 0,287]	[-0,481; 0,214]
Block c			[-0,411; 0,277]

The results suggested that the size of the blocks did exert no influence on the results of the questionnaire.

[56] The formula for finite populations (size lesser than 100.000 items) is: $(Z^2*Np*p*(1-p)) / ((Np-1)*k^2+Z^2*p*(1-p))$ where k stands for the error and Np represents the population size. When applied to our study: $Z^2*1467*0,5*0,5 / (1467*k^2+Z^2*0,5*0,5)$ it gives a value of 90 companies (being k= 10% and taken 95% as confidence level). 16 companies represent an error of 19% and a confidence level of 88%)

[57] This test assumes that both n_i and n_j (the sample sizes) are bigger than 30; it also recommends both p_i and p_j to be close to 0,5 (never lesser than 0,1 or bigger than 0,9). Although the first assumption is not satisfied, the second is.

[58] The intervals were calculated bu using the following expressions: [(pi-pj)-Za/2*SQRT((pi*(1-pi)/ni)+(pj*(1-pj)/nj); (pi-pj)+Za/2*SQRT((pi*(1-pi)/ni)+(pj*(1-pj)/nj)] where Za/2 is the abscisa of the N(0,1) that leaves on its right a/2 of probability.

3.4.4.1. RESULTS FROM GENERAL QUESTIONS

Out of the six recovery options (value or material recovery) mentioned in the hierarchy, the Recycling option was the one most of the companies in the sample adhered to, as is shown in Figure 20. This result was expected to certain extent.

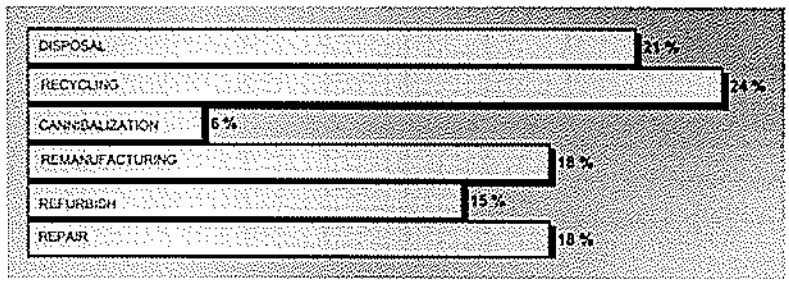


Figure 20. Recovery options accomplished by companies.

Figure 21 shows the percentage of companies that were involved in how many options. From it, it seems that companies have not yet fully internalised the recovery process as most of the companies are involved in only one or two out of the six possible recovery options.

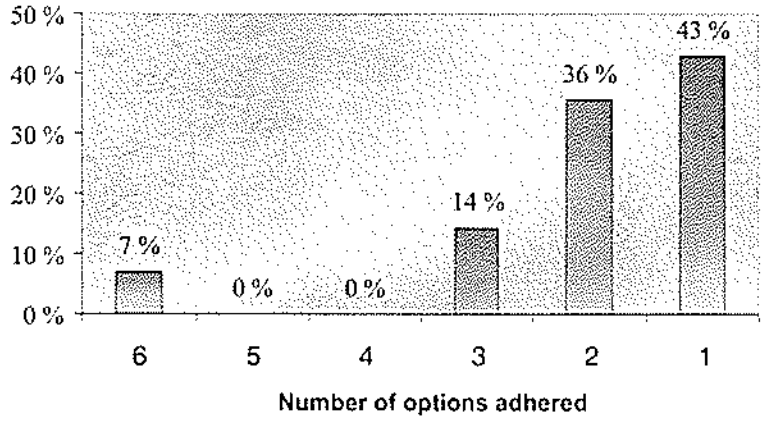


Figure 21. Percentages of involvement with different number of recovery options.

The degree in which these companies carry out in-house or outsource the logistics activities required for the return flows is depicted in Figure 22:

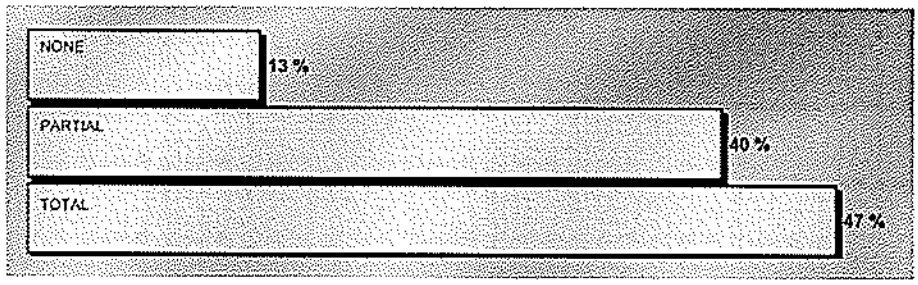


Figure 22. Level of reverse logistics activities outsourcing.

From this Figure, it can be easily appreciated that the majority of companies rely on third party logistics providers to accomplish part or the totality of their reverse logistics activities. Only a 13% carry them out in-house. This could be explained in one (or more) of at least four ways:

a) Financial resources: the current outsourcing trend in businesses seems to be not only one means for companies cutting costs down. It is also a strategic initiative to make the most of not affordable (most likely, in small size firms) technological advantages and skilled human resources with the aim of restructure the organization's operating model (Razzaque & Sheng 1998; Cottrill 2000; Wharton universia 2003).
b) Transaction costs: outsourcing may be a viable solution in organizations where the risks -legal, financial, etc.- are not very important (Maltz 1994); when these kind of risks are significant, transaction costs are usually greater and the trend is rather to vertical integration instead.
c) Priorities: according to the Winsemius & Guntram (1992) categorization of the stages of environmental awareness (reactive, receptive, constructive and proactive), companies with reactive posture will resort more often to outsource since they seem to use specialists to implement solutions they are required to, without internalising these competencies. Such companies could be instead dealing with other higher priority

challenges (according their own scales), still not solved, such as time or flexibility (Azzone & Noci 1998b).

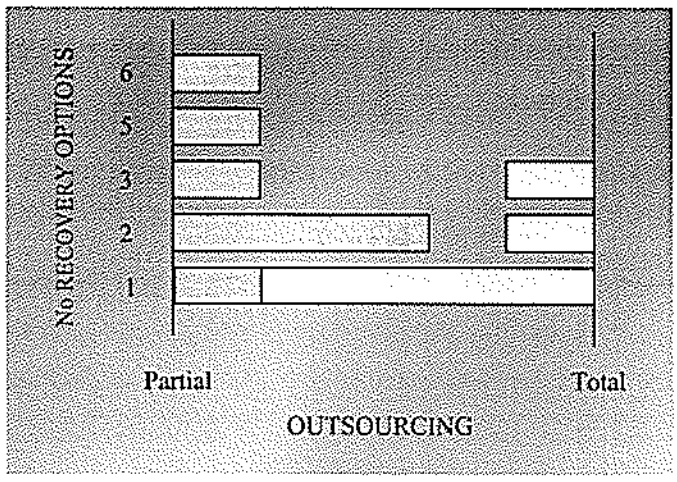


Figure 23. Relation between degree of outsourcing and number of recovery options carried out.

d) Elapsed time: the environment in which organizations operate has a big influence on their practices. However, companies usually do not start firmly with an environmental activity. It is only in a second phase, above all, if an external force presses them, when companies start to use environmental activities as a competitive weapon. Reverse logistics is a recent field and the results seem to confirm that most companies did not reach yet this second phase. This impression is reinforced by interrelating information from previous charts. The Figure 23 shows the relation between the commitment with recovery options (expressed by the number of adhered recovery options) and the degree of outsourcing.

The bigger the commitment with recovery options, the lesser the degree of outsourcing. Although the correlation ratio between these two variables (degree of outsourcing and commitment with recovery) is not impressive (0,42), certain degree of correlation cannot be denied. Assuming that this correlation exists, the reason behind could be found in the necessity of keeping a bigger control of the process. Thus, it is quite frequent that companies only involved in recycling and/or disposal rely on third party logistics providers to accomplish these tasks; this seems to especially be true when it comes to the collection

and transportation of the products or materials to the recyclers or landfills. By doing so, their businesses are not deviated from their core businesses. Benefits from carrying out these marginal recovery options in-house are not substantial enough to motivate the trouble, not in volume neither in range. In general terms, the situation could change if higher added value was recovered from returns. Let us take remanufacturing as an example. One company involved in remanufacturing needs to tune its production operations to combine traditional flows with returned flows. Thus, there is extra motivation to control the flows arrival rate to the company facilities, both in quantity and in time; this need of mastering the process could lead to the preference for not outsourcing the process or at least, not totally.

Although different schemes of outsourcing are possible, among the reverse logistics activities, transportation was the activity most often outsourced (35%), followed by warehousing (24%).

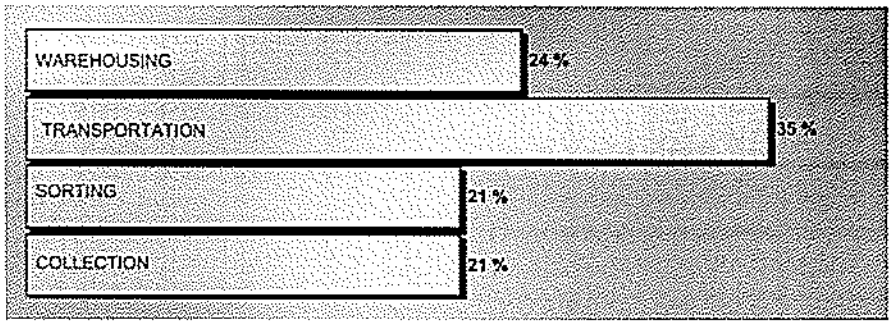


Figure 24. Percentage in which reverse logistics activities are outsourced.

It is probably not unreal to think that the financial risk posed with the investment needed for executing these activities, may deter companies from implementing them in-house. Actually, outsourced transportation was found to be notably more frequent in companies only involved in recycling and disposal.

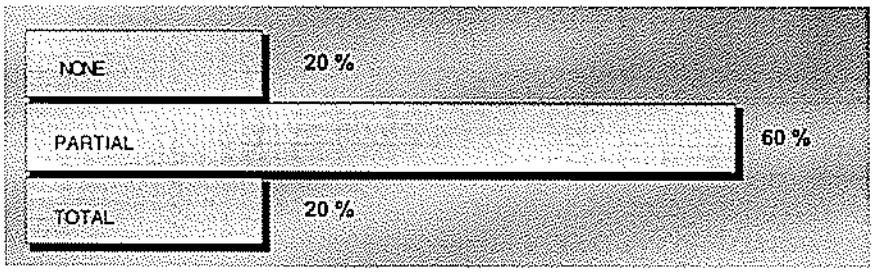


Figure 25. Level of integration between forward and backward chains.

Companies were also asked about the integration between forward and backward chains. 4/5 of them presented integration in some extent (whether total or partial). In _ of them, integration was only partial.

When integration is plausible without too much complexity, it is obviously a preferred solution for efficiency reasons. However, the specificity that the handling of returns requires, in most of the cases, makes easier to resort to resources and procedures independent from the forward chain, than to integrate both.

Finally, the situation of the company as regard its environmental certification was inquired as from previous research work a certain relation was detected in the sense that positive environmental stance could predispose companies to greater degree in reverse logistics activities involvement. Next Figure shows the percentages of companies that were certified according to some environmental standard. From this Figure we can see how 2/3 of the sample are not certified in any environmental standard nowadays.

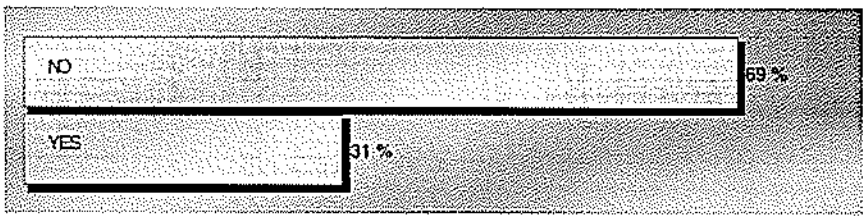


Figure 26. Environmental certification.

Even if reverse logistics is certainly a term managers are still nowadays unfamiliar with, the future perspective does not seem to be much more optimistic considering the amount of companies not yet environmentally certified. Environmental concerns both from public institutions and from customers have been the main driver for companies adopting reverse logistics practices. However, it seems that a long way needs still to be covered.

The relation between the fact of being certified in some environmental standard and any of the variables previously studied (outsourcing level, level integration or number of recovery options accomplished) could not been numerically supported.

3.4.4.2. RESULTS FROM AHP BLOCKS

As far as the AHP priorities given by the respondents is concerned, the following series of charts show the results.

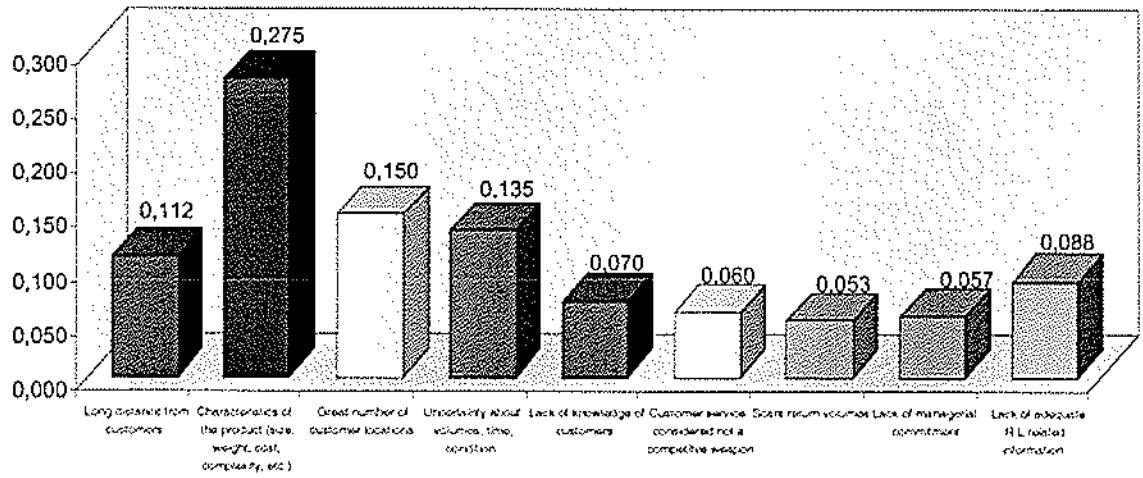


Figure 27. Priorities among problems when performing reverse logistics.

Priorities depicted in Figure 27 illustrate the prominent influence of product characteristics on the problems to face when considering implementing reverse logistics practices. Product characteristics weight stood out clearly from the rest factors considered in this

level of the hierarchy (nearly 0,3). The finding regarding the great number of customer locations having influence on reverse logistics decisions was strongly confirmed in this AHP study as this factor was given a second position in the ranking with a priority of 0,15, only a half way however from the product characteristics. Quite surprisingly, the uncertainty element did not come in the first place; literature has pointed out this feature as one of the most characteristic in reverse logistics environments and as one from which the majority of problems come from. In this analysis, respondents gave it a third position with an aggregated priority of 0,135. On the other side of the ranking, factors such as the scant return volumes or the lack of managerial commitment, both also highlighted in literature, only received 0,05 each.

The remarkable difference in the product characteristics priority seems to suggest that any design or decision related to reverse logistics implementation should first consider the restrictions imposed in each case by this variable.

The priorities given to the second set of elements were somehow also surprising. The aim of this block of questions was to determine the ranking of importance among for possible sources of external pressure when taking decisions on facing reverse logistics practices.

Customers influence was, already a priori, expected to be important but it resulted an element of extremely great significance, given that the priority assigned to this factor was 0,533 (the priorities of the remaining three factors together do not even level customers given priority). When this result is compared to the priority obtained by customer service in previous block of answers (0,060), the difference could, at first sight, seem contradictory. A more attentive consideration reveals that it is not. The study confirms how customers are the main driver to trigger companies towards their involvement in reverse logistics systems; customer concerns condition companies' stance in a specific direction. However, when it comes to the configuration of the backwards chain, consumer considerations keep a lower profile because if the chain has to be effective needs to be designed to meet products needs in first place; only by doing so, will customer needs be also satisfied.

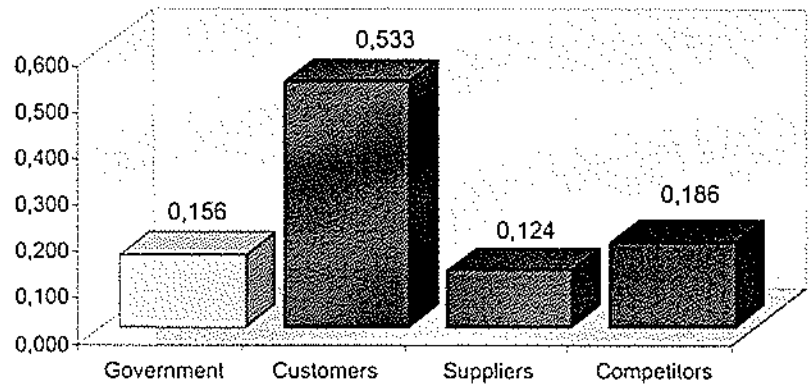


Figure 28. Priorities given to external pressures.

A second surprising result was the priority given to competitors, as from literature review and from the case studies the influence of this actor was far exceeded by the role played by governments. This fact could be the result of at least two reasons:

1. Following the widely known model provided by Wheelwright & Hayes (1985) for manufacturing strategies (internally neutral, externally neutral, internally supportive, externally supportive), this finding would locate companies in the second of the four-stage scale. In this second stage companies try hard not to lose parity with other competing companies, benchmarking their procedures and systems. This would make sense in industries where reverse logistics has already been internalised by the leading companies. The remaining players would need to imitate them to be equally qualified in the market.
2. The second explanation is that reverse logistics represents still a competitive advantage due to the lack of a pervaded implementation. Its adoption may offer to the organization an opportunity for developing a differentiation strategy, strategy measured in relation to what competitors do. Improved customer support or shorter cycle times may lead to better market share or new market niches (Goffin 1994).

Finally looking at the results from an overall perspective, it seems that the direction of influence is weaker when it comes from upward echelons in the chain, as suppliers stand the smaller priority. This finding could be taking as a symptom of the immaturity of the

reverse logistics internalisation process in companies. In a co-operative relationship among the members within the supply chain, reverse logistics could contribute to overall economic value creation.

In the third block of comparisons benefits or advantages stemmed from implementing reverse logistics processes were addressed to. Typical financial reasons, such as increase profitability and reduce costs, seem to strongly motivate organizations to go ahead; both together make roughly 0,5. Increasing customer service could also translate, in long-term, into better economical results and in this sense it is not wonder that this factor appears in the third place in the ranking. We could even add in this group the compliance with environmental legislation as, doing so, companies avoid penalties and therefore costs.

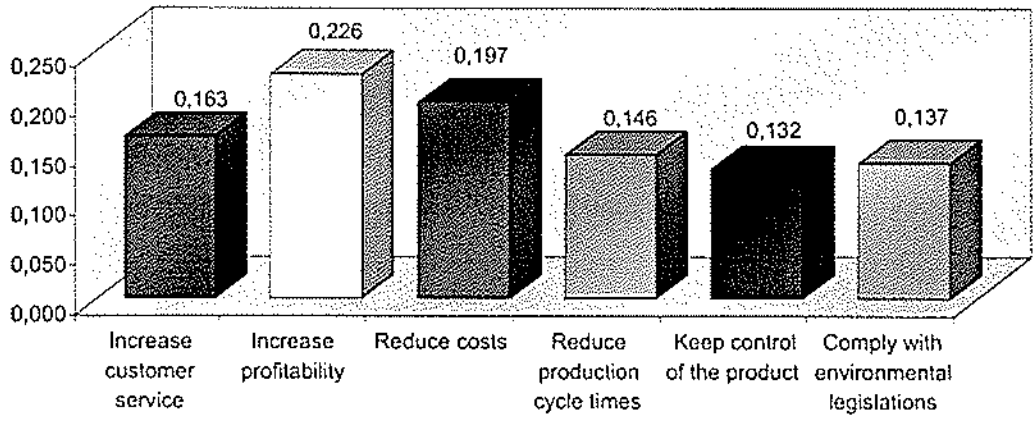


Figure 29. Priorities among objectives to reach by means of reverse logistics procedures.

Only 0,3 is left for not financial reasons. Financial perspective appears to be the most important consideration. This is in line with the results obtained by Montgomery *et al.* (2002) in their Logistics Report but as they point out, attention should be paid to avoid this financial perspective to jeopardize a more strategic view.

From previous block we have verified how important it is for companies to improve their economical position (priority bigger than 0,7). According to the last block of questions, the

promise of better financial results does not offset the problems posed by returns. The difficulties that respondents associate with the implementation of reverse logistics processes got a priority of nearly 0,5 (Figure 30). Their feeling about this criterion intuitively seems to be far more dissuasive than persuasive. Assuming this result to be true, the need to put more effort in informing companies and convincing them about the advantages is quite apparent. On the other hand, knowing that organizations give considerable credit to the pressure form external factors (second in the ranking with a priority of 0,3), the goal of spurring and fostering bigger commitment from companies should be kept in mind in governments and stakeholders' agendas.

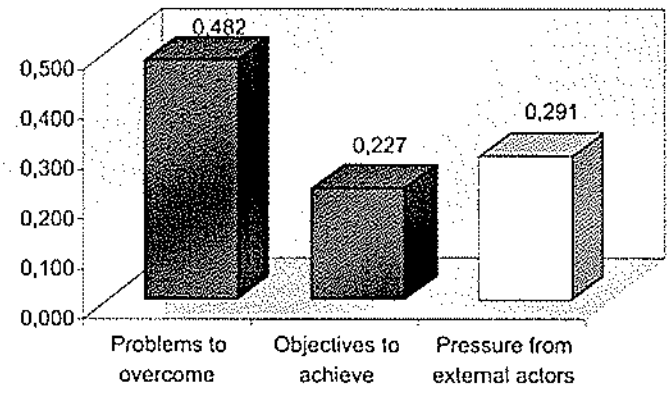


Figure 30. The priorities regarding the reasons affecting the decision on how to operate the reverse logistics practices.

The need to keep control of the product that surfaced as an important factor in a previous case study seems not to hold when a more ample number of companies are considered. Already some authors (Kearny 1994; Azzone & Noci 1998b) stated the impossibility to exert control over the entire product life cycle. In the light of Figure 29, companies seem to have assumed that fact as this objective was ranked the last. Only in special situations, such as products involving a certain degree of risk, the control would become a necessity.

Notice that external factor weight nearly one third of the 100%. It is the authors' interpretation of this result that, in general terms, companies have overcome the first stage

in their environmental awareness according to the framework given by Winsemius & Guntram (1992). The stance in which corporations react aseptically to external stimuli, that is, looking just for legal compliance has been termed as reactive. From the sample represented in Figure 30, some other considerations are to be regarded when delineating their reverse logistics strategy.

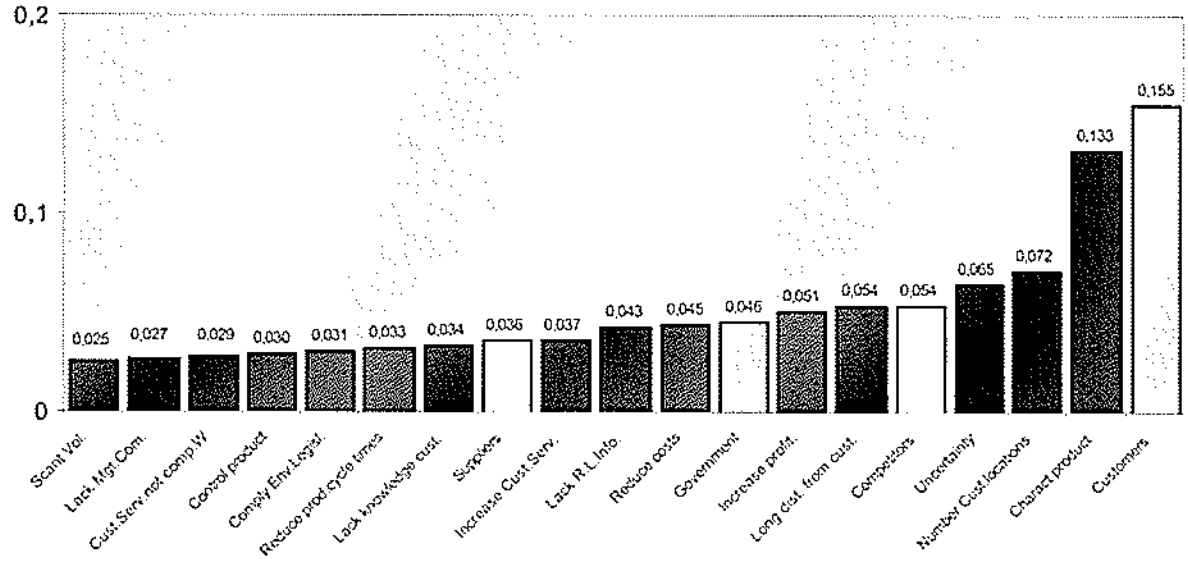


Figure 31. Weighted preferences.

Finally, the weighted preferences are represented in Figure 31. In it, a more comprehensive view of how all the considered attributes are related among each other is given. It is worth noticing that the position held by the first objective (increase profitability) appears behind six other attributes, or that the pressure from customers seems to be even more important than the significant problems posed by the characteristics of the product.

However, the fact of considering most critical criterion the one with the highest priority may be misleading according to Triantaphyllou & Sánchez (1997). One of the sensitivity analysis proposals of these authors is to measure the variation in weight needed for the best alternatives to change positions in the ranking. The smaller the variation the bigger the criticality. Our calculations (not included here) confirmed the pressure of external factors and the problems being more critical than the advantages from reverse logistics involvement.

3.4.5. CONCLUDING REMARKS

The work presented in this Section 3.4. is intended to aid in further development and enrichment of the reverse logistics conceptual framework. The main contribution of the present work has been to bridge a possible relation between the level of commitment with recovery activities and the level of outsourcing of the required reverse logistics activities. In this line and although intermediate stances are also considered, two categories of companies according to the reverse logistics and outsourcing policies adopted seem to stand out: companies fully committed with reverse logistics and companies where involvement is not so strong. The first type usually corresponds to big companies in size, where financial resources do not hinder in a significant way reverse logistics implementation. They are also commonly more involved and have a longer history in environmental issues; for them reverse logistics practices have disclosed to be an additional strategic tool in several senses: guarantee of better control of product, means of added value recovery, source of important information, extension of their customer service and weapon to succeed in market. Consumer requirements and product characteristics are present in their design stages. This first type of companies tends to outsource less often than the second type.

The link described in previous paragraph, although weak due to the size of the sample used, provides evidence of directions pointed out by Dunn (1999) for better decision making in "in-house versus outsource" context and will be further tested in future research work keeping in mind the following considerations.

Recalling the theory constructed by Williamson (1979) on transaction costs, three are the primary sources for such costs: transaction specific assets, uncertainty and frequency. The theory posits that the higher the level of these three variables the higher the probability for a company to internalise functions otherwise available from the market. One particular characteristic of returns is the uncertainty, what could lead to operate reverse logistics activities in-house. On the other hand, returns are not sent back on frequent basis what could point out to outsourcing as the best option between the both considered. It seems that a conflict arise when only the transaction costs approach is taken into consideration in the

analysis. Therefore, we believe that other forces may play an important role in the final decision. For instance, the company strategy: a cost leadership strategy could orientate company to outsource reverse logistics activities, providing this option is cheaper, whereas differentiation strategy would lead to keep them in-house (Maltz 1994); size of companies where the likelihood of integration is found to be bigger (Williamson 1983); value of the items, being high value and company direct involvement positively related (Lalonde & Cooper 1989); the type of industry (Maltz 1994).

On the other hand, and as far as the authors know, there are no previous studies where the relative importance of key variables in reverse logistics implementation is measured.

The adoption of environmental management systems (EMS) with which organizations are mainly invited to continuous source and waste reduction programs increase the interest in reverse logistics. However it seems that reverse logistics is rather driven by other factors. Organizational reverse logistics-related practices seem to be enforced by randomly patterns as far as previous environmental commitment is concerned.

Another interesting finding is related with the decision companies should adopt regarding their reverse logistics design. Figure 31 illustrates not only that both customers and characteristics of product were the two main influencing factors but also the disparity in relative weight when compared to others factors (they both roughly represent up to 30% out of the whole scale considered in this study). By conciliating these two leading aspects, corporations could more likely reach competitive advantages, as a strategic aspect of their policy (customers) would be harmonized with an operational one (product). It has been already stated how conformance with customer expectations is an order winning criterion (Hill 1994). This potential could be strengthened by jointly considering customer and reverse logistics future needs specifications in the product development phase.

Given the multiple interrelations that may be established among the aspects surrounding a reverse logistics system implementation (objectives, actors, problems, etc.) and given also the fact that AHP only considers one-way hierarchical relationships among the factors, the

possibility of applying ANP to the problem should be considered as an extension of this work.

Previous studies have found that demographic variables account for differences both in corporate environmental efforts (Murphy *et al.* 1995) and in logistics strategies (van Hoek & Commadeur 1998; Montgomery *et al.* 2002). From the small sample of companies included in this study, differences in reverse logistics practices could not clearly be observed among sectors of activity, position in the supply chain or firm size. Although some evidence was pointed out when explaining the reasons for outsourcing reverse logistics activities, the influence of these parameters on reverse logistics activities along with, other variables such as the organization culture, administrative heritage, managers' values, financial resources, human skills, etc. should be considered in future studies.

4. CONCLUSIONS

Operations strategy is crucial when it comes to the effectiveness of total strategy and thus corporate success (Porter 1995; Hayes & Upton 1998; Pilkington 1998). The linkages of Operations Management and Environmental Management render new possibilities for companies to recover and create value (Newman & Hanna 1996). Forward-looking companies have already taken measures regarding aspects such as Innovation and Design for Environment/Disassembly, specific arrangements for facilitating products collection and take-back, extension of product life (by highlighting repair, refurbishing and/or remanufacturing), and so on. They are conscious of the possibility of losing market against national or international competitors with superior performance. This process is therefore taking place although not yet to a great extent. It is the right time for observation, documentation and deeper understanding of such an organizational phenomenon.

This thesis has represented an attempt to satisfy that objective. In this vein, the relevance, priority in implementation and the degree of utilization of reverse logistics practices in companies was investigated. Its main contributions are presented in the next section followed by a section devoted to the limitations that should be kept in mind when assessing them. Finally, suggestions for future research are given.

4.1. CONTRIBUTIONS AND MANAGERIAL IMPLICATIONS

This research provides a number of valuable findings and implications about reverse logistics management in manufacturing companies. The first contribution encountered in this thesis is however the *proposal of a concept of the reverse logistics*. Even though a more precise concept may not have special transcendence in daily reverse logistics operations, it is our view that it is a must for academia to have clear theoretical frameworks and to reduce fuzziness from the polemic, disparate and sometimes confronting views about this topic found in literature. In the same line of search for clarification, we hope to have also contributed to better discern between green/environmental logistics and reverse

logistics practices. Although some connections may in certain cases be found, they should not be used as equivalent concepts.

Then, after adopting an inductive approach to come closer to the actual reverse logistics practices in real settings, valuable information about the initial research questions *(characteristics of the reverse logistics practices in durable and assembled goods manufacturing companies which include repair within their customer support service, factors that affect on their reverse logistics practices and how their businesses are affected by this new discipline)* was gathered and analysed so that theory building ("grounded theory" in terms of Glaser & Strauss 1967) could be later possible. Latent and manifest variables were identified and their influence measured; some constructs were also pinpointed.

We shall start this discussion by recalling the main factors that were found to have influence on the reverse logistics practices. The first factor could be referred to as *"the starting point"* of the company, that is, what is what the company has already achieved and what is still left to achieve (van Hoek & Commandeur 1998). Reverse logistics was found to be a low priority in companies that still have other more basic challenges, such as order fulfillment or flexibility, unsolved. Making a comparison with Maslow's hierarchy of needs (see e.g. Filley, House & Kerr 1976:184), reverse logistics do not belong to the lowest level of the pyramid (it is not a basic need for the company), rather to any other level but the lowest one. In this sense, reverse practices were more often implemented in well-established companies, with consolidated market shares and solid organizational procedures where basic challenges have been already faced; it was usual that these kind of companies were already concerned with environmental and sustainable issues. Their environmental sensitiveness was a factor that positively predisposed them to adhere to further commitments, such as reverse practices. Nevertheless, we have noticed *a more temperate relation between the degree of environmental commitment of a company and its level of involvement in reverse logistics processes* than the one that could be expected from literature.

Although there is no doubt that organizations nowadays are, in general terms, environmentally speaking more sensitive than in the past, *it is prudent not to talk, at the sight of the results put forward so far, of a clear prevalence in advanced reverse logistics operations neither in full commitment with sustainable practices*. The theoretical review of the concept did already provide a foundation, from the very beginning of the investigation, on how new this discipline was. Therefore some more time is probably needed for these new practices to be adopted in normal companies life. Although some reverse logistics implementation examples exist worldwide, they do not yet seem to constitute the rule in actual businesses. Throughout the empirical work carried out in this thesis we have illustrated and provided some evidence of this condition. The implication for firms is to realize that an increase in environmental and reverse issues responsiveness is possible given their actual positions; from there it is possible to attain better performance and added advantage.

Among those firms already involved in Reverse Logistics procedures, it was also possible to *determine which seem to be the most important parameters to affect the reverse logistics implementation; it was also possible to propose their relative importance from the companies' point of view*. The customers and the characteristics of the product were momentous determinants when it comes to reverse logistics decisions in our case companies, even exceeding the financial issues. It was also found that *their influence was not at the same level*. The customers have to be taken into consideration in the formulation of the reverse logistics strategy, whereas the product composition and architecture were seminal for the operational implementation of reverse logistics.

A fundamental issue in most debates about the nature of the strategy process is the extent to which strategy arises from whose intentions? Admitting that the most likely answer implies some kind of combination of different factors, this thesis has corroborated explicitly from the Focus Group and AHP work *the primacy of customers' influence on company strategic decisions on reverse logistics policies*. From the four types of external pressures, the customers stand out as the clearly most important from the remaining three from companies' standpoint. To succeed in future markets, organizations may need firstly to fully understand the criteria that define customers' requirements. The voice of the

customer has been proved to help organizations better delineate their strategies. According to Hill (1994) the criteria that define customers' requirements are divided in two differentiated groups. The first one is order-winning criteria (OWC) – criteria for which the customers decide on purchasing a specific product. The second type is qualifying criteria (QC), those that simply qualify the company to be in the market; as such they constitute *sine qua non* conditions. Some companies already involved in reverse logistics practices have realized how the incorporation of these practices have brought the differentiation or competitive advantage needed for gaining market share to their businesses. This favourable position will not last forever, so the adoption of the reverse logistics practices will probably become a simple qualifying criterion in a no far future. The implication for firms is to become aware of the time span they have to realize the benefits from the early implementation of reverse logistics practices; competitive edge is usually only available for those companies who move first. Anyway, organizations should also take for granted that the movement is unavoidable as the changes in markets orientate more and more to customers, and their demands require sustainable and cost effective practices.

With regards to the second determining factor, the characteristics of the product, they were also investigated in more detail. Not only the physical features such as volume, size, weight, but also the risk, complexity, modularity, value, etc. should definitely be highly considered before adopting any final decision on the design of the reverse logistics systems. Firms should be fully conscious that some reverse logistics decisions belong to the strategic sphere of the company. Therefore, these decisions should be carefully made so that they are integrated in the other goals and policies of the organization in a cohesive way, without jeopardising resources or future actions.

After understanding that reverse logistics may be an order winning criteria, companies need to make the relevant decisions. As in total quality management implementation, managerial commitment is first needed for streamlining the process. Quite often it may even happen that the group in charge of developing reverse logistics programs or of deciding on them is not even a logistics related group (Stock 1998). The cases studied in this thesis seem not to cast a very optimistic view of the reality: *returns do not yet seem to represent an area to which managers would pay much attention*. Several reasons may

explain this attitude. Firstly, there is a lack of a full body of knowledge to which managers could resort to get familiar and to find framework for possible solutions. Secondly, and to certain extent related to the previous reason, there seems to be a resistance to changes and to incorporate modifications in the actual logistics systems (due to the emerging nature of the reverse logistics, managers may feel uncertain how to cope with it). Finally, for making sound decisions reliable information is needed. During this work, the evidence reinforced the idea that *decision-makers were not yet properly supported.* The challenge, in most organizations involved with returns, is *finding reasonably accurate data with regard to several areas*. On the one hand, the lack of reliable *forecasts* makes it difficult to compensate the uncertainty inherent to returns regarding quantities, times, condition, variety. On the other hand, lack of *ad-hoc* software makes it difficult to track the returns, their location, customers who sent them back, suppliers of the returned product components, etc. There is also a need to develop *performance measures* and finally, a necessity of fighting against the absence of *costing methods* with which being certain of the tradeoffs among different options or decisions. Although one appropriate tool for accurate decision-making could be to use Life Cycle costing approach, decisions are still made without accurate information, assuming high risks of adopting wrong decisions, with sometimes adverse and expensive results. Sometimes the problem is not even that information is not accurate but that simply it does not exist (Tan, Yu & Ho 2001). Firms are more likely to better manage changes and increase in their overall performance if accurate information on abovementioned topics is timely provided.

Another research question posed in this thesis referred to how the businesses are affected by this new logistics discipline (or how they are reacting to it). The organizations analysed in this work, in general terms, do not seem to be affected neither to be adopting particular measures to react in any special way. The apparent little direct impact of returns in corporate results and the legislation not yet in full power seems to cause companies to neglect this aspect of their businesses. The only decision observed has to do with outsourcing. In this sense, another important contribution of the present work has been *to bridge a possible relation between the level of outsourcing of the required reverse logistics activities and the level of commitment with recovery activities. Justifications were also given based not only in transaction costs theory; it was argued how this theory did not*

fully explain reverse logistics outsourcing decisions mainly due to the peculiarities of this reverse environment. Kokkinaki, Dekker, de Koster & Pappis (2001:7) contend that "in-house reverse logistics seems appropriate for those [companies] who can capitalize on their previous experience on returns management" but they do not provide a taxonomy that could help to recognize them with even some likelihood.

As pointed out in Section 3.4. and in answer to the third research question, we have detected two main categories of companies according to the reverse logistics and out-sourcing policies adopted. The size, their financial resources, environmental stance, strategic consideration of their reverse logistics practices, the importance assigned to their customers, and the considerations of the future reverse logistics needs in the early design stage of their product development are features that seem to clearly differentiate these two basic types.

This categorization could also explain the *role played by competitors in shaping companies' strategies.* In our opinion the leading companies pay more attention to their competitors than reactive companies. These companies find in their on-par competitors a stimulus not to lose opportunities in the market. At the same time, when comparing themselves to non-threatening competitors, they try to keep distance so that to maintain their competitive advantage from a more advanced or innovative procedures.

A final contribution refers to the characterization of not a sole company but the whole supply chain. It was revealing *to verify the different weight conceded to upstream members of the supply chain when compared to downstream supply chain*, the latter being clearly more significant when decisions on reverse logistics systems have to be made. This fact corroborated the immaturity in the actual reverse logistics internalisation process in companies and could be attributed to the short sight of potential created value and benefits that could be derived from a more co-operative and co-ordinated chain.

4.2. LIMITATIONS

The limitations of the study presented in this thesis have been already mentioned in the respective sections, these limitations being mainly derived from the methodologies used for the empirical work. Two typical and important disadvantages regarding the case study methodology when compared to quantitative research are the difficulties for replication and for generalization. These limitations are derived for inherent features of the case studies: relative subjectivity, small size sample used in the study and lack of a "random" selection. While these limitations are unavoidable in the application of the methodology, the preliminary results can be later supported with investigations involving a more ample sample.

One could argue that the empirical part of the thesis could have been broader than what it actually is. Regarding this potential remark the following facts should be kept in mind. Firstly, as it was already mentioned, more companies than the ones reflected in the text were indeed contacted as possible candidates for a greater number of case studies. Their low involvement (or non-involvement) in reverse logistics practices in some cases, and the little significance given to their reverse flows in some other, drove us to not explicitly considered them in separate sections although insight from their experiences was embedded in the text. Secondly, the AHP questionnaires were sent to nearly 200 firms. Answers were expected to be much higher in amount than they were.

One possible reason to back the logic behind could be the paucity of theoretical models. It has been already pointed out the emerging character of the reverse logistics discipline. Theoretical framework needs more research contributions to expand the knowledge and the understanding of reverse logistics in industry (Krumwiede & Sheu, 2002). If practitioners benefit by being provided with a deep understanding of the strategic processes at work within their organizations (Barnes 2001: 1078), without an appropriate framework, it would be understandable that managers may not feel eager to discuss openly about the topic. Third, if according to Griggs (1987) large samples are not necessary to guarantee generalizability, a term linked with quantitative research where verification is pursued, large samples should not be expected in qualitative research where small samples are a

characteristic feature of the method. On the other hand, findings from research need only be probable not necessarily probative (Overholser 1986). The significance levels in bigger-sample qualitative studies also mean that there is only a probability that the results are correct within the sample - and most of the samples are just approximations of a real normal distribution curve. Thus, at least in business studies, the research results are practically never fully true but a probable representation of reality (Kekäle 2001: 557-558).

With respect to the AHP, higher levels of consistency could have been reached by insisting on explaining to managers how the assessments should be made and therefore obliging them to spend a precious time that they were already reluctant to spend the first time. On the other hand, the interconnections among different factors and criteria were not considered.

4.3. SUGGESTIONS FOR FUTURE RESEARCH

Reverse logistics serves at different purposes. On one hand, it takes an indispensable part of a broader event, the Recovery Management, as regards to which both population and governments are more and more concerned from a sustainable standpoint. On the other hand, it has been said to be the last frontier for companies to cut down costs. However, because it is such a recent research field, the possibilities for further research are still many.

Although it has been suggested on environmental grounds, it *has not yet empirically been addressed whether the extent to which a firm strategy is proactively committed to reverse logistics affects its capacity to create additional value.* Studies with positive results in this direction would be more than welcome to have objective instruments with which convince companies to open to this new functional area in their businesses. One suggestion, not yet seen in literature and which combines the previous goal with a research area indicated in the focus group, would be to use the ServQual Methodology (Parasuraman, Zeithaml & Berry 1988). This methodology has proved to be a valuable tool for organizations to better

understand what customers' value and how well their current organizations are meeting the needs and expectations of the customers.

Additional areas for further research proposed by the Focus Group would include to investigate the rationale for the lack in corporations' self motivation when it comes to face product returns management (also evident in the case studies). Furthermore, the Focus Group emphasised studying the ways to foster the use of LCA, innovative methods to achieve economies of scale, and new methods to improve accuracy of forecasting mainly times and quantities in which returns will take place.

One feature that has been highlighted in several parts of this document has been the *necessity for reliable information on the costs linked with returns*, as one of the key tools for decision-making processes. Yet, there is not unanimity on how those returns should be valued neither on the criteria to incorporate them to the accounting systems. Because their cause may be rooted in hidden, remote areas, without reliable information is impossible to fully understand their business impact.

Several authors have claimed that the reduction of transaction costs as a consequence of the utilization of information technologies sponsor further outsourcing (see list in Kakabadse & Kakabadse 2000:672). Hence, also the interest in investigating *how decisions, such as shifting from outsourcing reverse logistics activities to in-house practices, or twisting from one reverse distribution channel to another, have been triggered from adopting better communications systems,* implementing www technologies, etc., is related to the information topic. In other words, it would be of value to know how these information technologies have contributed to alter previous managerial strategies and to which extent.

Literature also provides with works stating that *when a service (or product) reaches a "commodity" status and loses its differentiated advantage, providers resort more to outsource them* (Venkatraman 1997; Murray & Kotabe 1999). A follow-up of the future reverse logistics evolution in markets could bring evidence to confirm or refute this

relationship. As far as the authors are concerned no previous work has focused on the contractual terms used with outsourcing companies in the reverse logistics context.

We have in this thesis focused mainly on companies that occupy the position of *manufacturer* in the supply chain, companies involved in only one of the possible range of recovering activities (*repair*) and companies that satisfying the two previous conditions, produce and operate with *durable goods*. From these three constraints, three possible directions in which further research would be desirable result obvious. As more actors intervene in the process and contribute to its overall efficiency, their inclusion in future studies would bring not only a deeper knowledge about their individual role and problems but also a better integral perspective of the whole chain. Although some studies have already been published covering other recovery options different from repairing, they are still a few.

We also miss a greater number of specific case studies by means of which more evidence about companies' responses could be gathered. This affirmation connects to another limitation of this work. Although the AHP study was accomplished with the participation of a bigger sample of companies, offsetting the small number of them included in the case studies, the results cannot yet been fully extrapolated so as to build a really robust theory from them. Only if the incorporation of a *large number of companies*, activities and products occurs, it will be possible to sufficiently prove the correctness of such a theory. This also goes along with quantitative approaches. In this thesis we have mainly used qualitative tools to collect the information and to process it. The use of *complementary methodologies* would bring synergetic outcomes to the ones already obtained.

When applying the AHP in this thesis, we came across to an approach similar in objectives but a more ambitious, which is called "Analytical Network Process" (ANP). The advantage of *using ANP* is that, where AHP only considers one-way hierarchical relationships among factors, ANP allows the inclusion of these interdependencies, or internal feedback among the elements in the hierarchy, bringing out more accuracy and consistency in the analysis (Sarkis & Talluri 2002). This feature was found to be very useful when it comes to reverse logistics as many aspects are interrelated. It was not used in this work because the

computational and data requirements of the ANP approach, in practical applications, make the analysis task too cumbersome and the desired test results could more easily be reached by AHP. Nevertheless, the author is convinced that its use could positively contribute to refine the previous results.

Another topic that would be challenging to study are the mechanisms by means of which *co-operation between different functional teams within a firm or between different actors in the chain, mainly those engaged in the reverse chain, could be effectively motivated and stimulated.* Additionally, to investigate the reasons behind the *unbalance conceded to upstream members when compared to downstream members* in reverse logistics would be of great interest.

Because the design stages both in product development and in the reverse logistics network planning is seminal, we feel that *Taguchi methods* have being neglected in reverse logistics context. These methods (also together with some other methodologies called "Robust Design" methods; see e.g. Gitlow, Gitlow, Oppenheim & Oppenheim 1989:491-509 for a short introduction) allow companies to rapidly and accurately acquire technical information to design and produce low-cost, highly reliable (products and) processes. These methods focus on quality problems related to their design stage, ensuring better performance and expressing it in monetary terms. This is accomplished by explicitly considering the outside influences over which company has little or no control.

Finally, different research paradigms can possibly be addressed in reverse logistics arena. Given that certain analogies do exist between forward and reverse logistics, the adoption of the so labeled as *"Transfer of technologies strategy"* could be used to transpose what is known in traditional logistics in order to better model reverse logistics domains. In the same line, the so-called "*Creative application strategy*" could also bring knowledge and applications from other areas.

REFERENCES

Ackerman, K. (1997). *Practical Handbook of Warehousing*. 4 ed. Kluwer Academic Publishers. ISBN: 0412125110.

Ammons J., M. Realff & D. Newton (1997). Reverse production system design and operation for carpet recycling. *Working Paper*, Georgia Institute of Technology, Atlanta.

Andel, T. (1995). There's power in numbers. *Transportation and Distribution* 36:8, 67-68.

Andel, T. (1997). Reverse logistics: a second chance to profit; whether through refurbishing or recycling, companies are finding profit in returned products. *Transportation and Distribution* 38:7, 61–64.

Andersen, I., F. Borum, P. Kristensen & P. Karnoe (1995). *On the Art of Doing Field Studies*. Denmark: Finn Borum. ISBN: 87-16-13269-6.

Angell, L. & R. Klassen (1999). Integrating environmental issues into the mainstream: an agenda for research in operations management. *Journal of Operations Management* 17:5, 575–598.

Anonymous. (2000). Less expensive process for paper recycling. *Biocycle*, September, 41:9, 21.

Armistead, C. & G. Clark (1992). *Customer service and support*. London: Pitman.

Ashayeri, J., R. Heuts & A. Jansen (1999). Inventory management of repairable service parts for personal computers: A case study. *Discussion Paper 99* / Tilburg University, Centre for Economic Research (web site) (RePEc:dgr:kubcen: 1994–99).

Autry, C., P. Daugherty & R. Richey (2001). The challenge of reverse logistics in catalogue retailing. *The International Journal of Physical Distribution & Logistics Management* 31:1, 26–37.

Axelrod, M. (1975). 10 essentials for good qualitative research. *Marketing News* 8, 10–11.

Ayres, R., G. Ferrer & T. Van Leynseele (1997). Eco-efficiency, asset recovery and remanufacturing. *European Management Journal* 15:5, 557–574.

Azzone, G., R. Bianchi, R. Mauri & G. Noci (1997). Defining operating environmental strategies: programmes and plans within Italian industries. *Environmental Management and Health* 8:1, 75–84.

Azzone, G. & G. Noci (1998). Identifying effective PMSs for the deployment of "green" manufacturing strategies. *International Journal of Operations & Production Management* 18:3/4, 308–335.

Azzone, G. & G. Noci (1998b). Seeing ecology and "green" innovations as a source of change. *Journal of Organizational Change Management* 11:2, 94–111.

Ballou, R. (1992). *Business Logistics Management*. 3 ed. Prentice Hall International Inc. ISBN: 0130934100.

Ballou, R., Gilbert S. & A. Mukherjee (2000). New managerial challenges from supply chain opportunities. *Industrial Marketing Management* 29:1, 7–18.

Bana e Costa, C. & J. Vansnick (1994). MACBETH: an interactive path towards the construction of cardinal value functions. *International Transactions in Operational Research* 1:4, 489–500.

Barnes, D. (2001). Research methods for the empirical investigation of the process of formation of operations strategy. *International Journal of Operations & Production Management* 21:8, 1076–1095.

Barry, J., G. Girard & C. Perras (1993). Logistics planning shifts into reverse. *Journal of European Business* 5:1, 34–38.

Bartholomew, D. (1984). The vendor-customer relationship today. *Production and Inventory Management Journal* 25:2, 106–21.

Barzilai, J. (2001). Notes on the analytical hierarchy process. *Proceedings of the NSF Design and Manufacturing Research Conference*, January. Tampa. Florida.

Bayles, D. (2000). Send it back! The role of reverse logistics. In: *E-Commerce Logistics and Fulfillment: Delivering the Goods*. 1 ed. Prentice Hall. ISBN: 0130303283.

Beckley, D. & W. Logan (1948). *The Retail Salesperson at Work*. New York, NY: Gregg Publishing.

Bellmann, K. & A. Kahre (2000). Economic issues in recycling end-of-pipe vehicles. *Technovation* 20:12, 677–690.

Benayoun, R., B. Roy & B. Sussman (1966). ELECTRE: une méthode pour guider le choix en présence des points de vue multiples. *Technical Report, SEMA-METRA International, Direction Scientifique, Note de travail 49.*

Biddle, D. (1993). Recycling for profit: The new green business frontier. *Harvard Business Review* 71:6, 145–156.

Bloemhof-Ruwaard, J.M., P. van Beek, L. Hordijk & L.N. Van Wassenhove (1995). Interactions between operational research and environmental management. *European Journal of Operational Research* 85:2, 229–243.

Bloemhof-Ruwaard, J., J. van Nunen, J. Vroom & A. van der Linden (2001). One and two way packaging in the dairy sector. *118 in Discussion Paper from Erasmus Research Institute of Management (ERIM),* Erasmus University Rotterdam. Available: http://econpapers.hhs.se/paper/dgreureri/2001118.htm.

Blumberg, D. (1999) Strategic examination of reverse logistics and repair service requirements, needs, market size, and opportunities. *Journal of Business Logistics* 20:2, 141–159.

Blumer, H. (1969). *Symbolic Interactionism. Perspective and Method.* Berkley: University of California Press.

Bodin, L. & S. Gass (2003). On teaching the analytic hierarchy process. *Computers & Operations Research* 30:10, 1487–1497.

Bossink, B. & H. Brouwers (1996). Construction waste: Quantification and source Evaluation. *Journal of Construction Engineering & Management* 122:1, 55–60.

Botter, R. & L. Fortuin (2000). Stocking strategy for service parts – a case study. *International Journal of Operations & Production Management* 20:6, 656–674.

Bowen, F., P. Cousins, R. Lamming & A. Faruk (2001). The role of supply management capabilities in green supply. *Production and Operations Management* 10:2, 174-189.

Bowersox, A. (1986). *Logistical Management; a Systems Integration of Physical Distribution Management, Material Management, and Logistical Coordination.* New York: McMillan Publishing. ASIN: 0023130504.

Brennan, L., S. Gupta & K. Taleb (1994). Operations planning issues in an assembly/ disassembly environment. *International Journal of Operations & Production Management* 14:9, 57–67.

Brimer, R. (1995). Logistics networking. *Logistics Information Management* 8:4, 8–11.

Brockmann, T. (1999). 21 warehousing trends in the 21st century. *IIE Solutions* 31:7, 36–40.

Byers, P. & J. Wilcox (1991). Focus group: A qualitative opportunity for researchers. *The Journal of Business Communication* 28:1, 63–78.

Cairncross, F. (1992). How Europe's companies reposition to recycle. *Harvard Business Review* 70:2, 34–45.

Calder, B. (1977). Focus group and the nature of qualitative marketing research. *Journal of Marketing Research* 14:Aug, 353–364.

Caldwell, B. (1999). Reverse logistics. *Information Week*, April. http://www.informationweek.com/729/logistics.htm.

Campbell, D. (1975). Degrees of freedom and the case study, *Comparative Political Studies* 8:3, 178–193.

Carliss, Y., C. Baldwin & B. Clark (1997). Managing in the age of modularity. *Harvard Business Review* 75:5, 84–93.

Carr, A. & J. Pearson (2002). The impact of purchasing and supplier involvement on strategic purchasing and its impact on firm's performance. *International Journal of Operations & Production Management* 22:9, 1032–1053.

Carter, C. & L. Ellram (1998). Reverse logistics: A review of the literature and framework for future investigation. *Journal of Business Logistics* 19:1, 85–102.

Cespedes, F. (1995). *Concurrent Marketing: Integrating Product, Sales, and Service.* Boston: Harvard Business School Press. ISBN: 0875844448.

Chase, R., N. Aquilano & F. Jacobs (1998). *Production and Operations Management, Manufacturing and Services*. 8 ed. Boston: Irwin McGraw-Hill. ASIN: 0071152229.

Christopher, M. (1997). *Marketing Logistics*. Butterworth-Heinemann, Great Britain

---------- (1998). *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service*. 2 ed. Financial Times Prentice Hall. ISBN: 0273630490.

Cohen, M., Y. Zheng & V. Agrawal (1997). Service parts logistics: A benchmark analysis. *IIE Transactions* 29:8, 627–639.

Cottrill, K. (2000). Return to sender. *Traffic World* 262:7, 17–18.

Council of Logistics Management (1989). *Leading Edge Logistics: Competitive Positioning for the 1990's*. Illinois: Oakbrook.

Cox, K., J. Higgenbotham & J. Burton (1976). Applications of focus group interviews in marketing. *Journal of Marketing* 40:1, 77–80.

da Cunha, A. & A. Giacomucci (2002). Green procurement activities: some environmental indicators and practical actions taken by industry and tourism. *International Journal of Environment and Sustainable Development* 1:1, 59–72.

Daugherty, P., M. Myers & R. Richey (2002). Information support for reverse logistics: the influence of relationship commitment. *Journal of Business Logistics* 23:1, 85–106.

Dawe, R. (1995). Reengineer your returns. *Transportation and Distribution* 36:8, 78–80.

de Brito, M., S. Flapper & R. Dekker (2002). Reverse logistics a review of case studies. *Econometric Institute Report Series EI 2002-21*, Erasmus University Rotterdam, The Netherlands.

de Ron, Ad. & K. Penev (1995). Disassembly and recycling of electronic consumer products: an overview. *Technovation* 15:6, 363–374.

Dekker, R., M. Kleijn & P. de Rooij (1998). A spare parts stocking policy based on equipment criticality. *International Journal of Production Economics* 56-57, 69–77.

Del Castillo, E. & J. Cochran (1996). Optimal short horizon distribution operations in reusable container systems. *Journal of the Operational Research Society* 47:1, 48–60.

Diaz, A. & M. Fu (1997). Models for multi-echelon repairable item inventory systems with limited repair capacity. *European Journal of Operational Research* 97:3, 480–492.

Donker, S. & T. van der Ploeg (2001). Multi-echelon voorraadbeheersing voor repareerbare reserveonderdelen bij Lucent Technologies Nederland. *Handbook of reverse logistics*. Ed. S.D.P. Flapper and C. Clement.

Dowlatshahi, S. (2000). Developing a theory of reverse logistics. *Interfaces* 30:3, 143-155.

Drumwright, M. (1994). Socially responsible organizational buying: environmental concern as a non-economic buying criterion. *Journal of Marketing* 58:3, 1–19.

Duhaime, R., D. Riopel & A. Langevin (2000). Value analysis and optimisation of reusable containers at Canada Post. *Interfaces* 31:3, 3–15.

Dunn, S. (1999). Repair versus replace. *Proceedings of Asian Maintenance in Mining Conference*. Lombok, Indonesia.

Dy-Dee Diaper Service. Available: http://www.dy-dee.com.

Dyer, J. (1990). Remarks on the analytic hierarchy process. *Management Science* 36:3, 249–258.

Dyer, W. & A. Wilkins (1991). Better stories, not better constructs to generate better theory: A rejoinder to Eisenhardt. *Academy of Management Review* 16:3, 613–619.

Eisenhardt, K. (1989). Building theories from case study research. *Academy of Management Review* 14:4, 532–550.

Eisenhardt, K. (1991). Better stories and better constructs: The case and comparative logic. *Academy of Management Review* 16:3, 620-627.

Elkington, J. (1994). Towards the sustainable corporation: Win-win-win business strategies for sustainable development. *California Management Review* 36:2, 90–100.

Ellram, L. (1996). The use of the case study meted in logistics research. *Journal of Business Logistics* 17:2, 93–138.

Emerson, C. & C. Grimm (1996). Logistics and marketing components of customer service: an empirical test of the Mentzer, Gomes and Krapfel model. *International Journal of Physical Distribution & Logistics Management* 26:8, 29–42.

Environmental Sustainability Index Ranking 2002 of the World Economic Forum. Available: http://www.ciesiNocolumbia.edu/indicators/ESI/rank.html.

European Commission Directorate-general environment. Available: http://www.europa.eu.int/comm/environment/newprg/index.htm.

Faltermayer, E. (1972). Metals: The warning signals are up. *Fortune* October, 110.

Farrell, P. & S. Heinritz (1981). *Purchasing: Principles & Applications*. 6 ed. Prentice Hall. ISBN: 013742163X.

Fava, J. (1991). Product lifecycle assessment: improving environmental quality. *Integrated Environmental Management* 3:October, 19–21.

Fern, E. (1982). The use of focus groups for idea generation: The effects of group size, acquaintanceship, and moderator on response quantity and quality. *Journal of Marketing Research* 19, 1–3.

Fernández, I. (2003a). The concept of reverse logistics. A review of literature. *Proceedings of 15th Annual NOFOMA'03 Conference*. Oulu. Finland. ISBN: 951-42-7064-9.

Fernández, I. (2003b). Effects on purchasing function as a result of recovery activities. *Proceedings of CISIM'03 Conference*. Elk. Poland. ISBN: 83-87256-55-2.

Fernández, I. (2003c) Household waste collection: a case study. *Proceedings of the LOADO'2003 Conference*. Eslovaquia. ISSN: 1451-107X.

Fernández, I., N. García, J. Puente & M. Mitre (2003) Municipal solid waste. A comparative study in two European countries. *Proceedings of International Conference on Industrial Logistics, ICIL'2003*. ISBN: 952-476-0101-X.

Fernández, I. & B. Junquera (2003). The role of reverse logistics in repair customer support. Two companies under test. *Proceedings of QMOD Conference*. October, Paris, France.

Fernández, I. & M. Korpilähde (2003). Tracking the bond between environmental issues and reverse logistics. Is it so strong? *Proceedings of RSC2004 Conference.* Coimbatore, India.

Ferrer, G. & R. Ayres (2000). The impact of remanufacturing in the economy. *Ecological Economics* 32, 413–429.

Ferrer, G. & D. Whybark (2000). From garbage to goods: successful remanufacturing systems and skills. *Business Horizons* 43:6, 55–64.

Ferrer, G. & D. Whybark (2001a). Material planning for a remanufacturing facility. *Production and Operations Management* 10:2, 112–124.

Ferrer, G. & D. Whybark (2001b). Communicating product recovery activities. Processes, Objectives and Performance Measures. In Handbook of *Environmentally Conscious Manufacturing 2001*, edited by Christian N. Madu, chapter 4, pp. 81–100. Boston: Kluwer Academic Publishers.

Fleischmann, M., J. Bloemhof-Ruwaard, R. Dekker, E. van der Laan, J. van Nunnen & L. van Wassenhove (1997). Quantitative models for reverse logistics: A review. *European Journal of Operational Research* 103:1, 1–17.

Fleischmann, M. (2000). *Quantitative Models for Reverse Logistics.* Springer- Verlag.: 3540417117.

Fleischmann, M., P. Beullens, J. Bloemhof & L. Wassenhove (2001). The impact of product recovery on logistics network design. *Production & Operations Management* 10:2, 156–173.

Fleischmann, M., H. Krikke, R. Dekker & S. Flapper (2000). A characterization of logistics networks for product recovery. *Omega* 28:6, 653–666.

Fleischmann, M., J. van Nunen & B. Gräve (2002). Integrating Closed-loop Supply Chains and Spare Parts Management at IBM. *No 267 in Discussion Paper from Erasmus Research Institute of Management (ERIM).* Erasmus University Rotterdam. http://econpapers.hhs.se/paper/dgreureri/2002267.htm.

Filley, A., R. House & S. Kerr (1976). *Managerial Process and Organizational Behaviour.* 2 ed. The USA: Scott, Foresman and Company. ISBN: 0-673-07857-4.

Forman, E. & K. Peniwati (1998). Aggregating individual judgments and priorities with the Analytic Hierarchy Process. *European Journal of Operational Research* 108:1, 165–169.

Fortuin, L. & H. Martin (1999). Control of service parts. *International Journal of Operations & Production Management* 19:9, 950–971.

Gertsakis, J., N. Morelli & Ch. Ryan (1998). *Return to Sender. An Introduction to Extended Producer Responsibility*. Australia: The National Centre for Design at RMIT. ISBN: 0864447469.

Ginter, P. & J. Starling (1978). Reverse distribution channels for recycling. *California Management Review* 20:3, 73–82.

Gitlow, H., S. Gitlow, A. Oppenheim & R. Oppenheim (1989). *Tools and Methods for the Improvement of Quality*. USA: Richard D. Irwin, Inc. ISBN: 0-256-05680-3.

Giultinian, J. & N. Nwokoye (1975). Developing distribution channels and systems in the emerging recycling industries. *International Journal of Physical Distribution* 6:1, 28–38.

Giuntini, R. & T. Andel (1994). Track the comings, goings, & costs of returnables. *Transportation & Distribution* 35(7): 55–58.

Giuntini, R. & T. Andel (1995a). Advance with reverse logistics: Part 1. *Transportation & Distribution* 36:2, 73–75.

Giuntini, R & T. Andel (1995b). Master the six R's of reverse logistics: Part 2. *Transportation & Distribution* 36:3, 93–98.

Giuntini, R. & T. Andel (1995c). Reverse logistics role models – Part 3. *Transportation & Distribution* 36:4, 97–98.

Glaser, B. & A. Strauss (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New York: Aldine de Gruyter. ISBN: 0-202-302260-1.

Goffin, K. (1999). Customer support; a cross-industry study of distribution channels and strategies. *International Journal of Physical Distribution & Logistics Management* 29:6, 374–398.

Goldman, A. (1962). The group depth interview. *Journal of Marketing* 26, 61–68.

Goldsby, T. & D. Closs (2000). Using activity based costing to reengineer the reverse logistics channel. *International Journal of Physical Distribution & Logistics Management* 30:6, 500–514.

Goldsby, T. & T. Stank (2000). World class logistics performance and environmentally responsible practices. *Journal of Business Logistics* 21:2, 187–208.

Goodyear, M. (1990). Qualitative research. In: *A Handbook of Market Research*. London: E Birn, R., Hague, P. and Valgelder, P., Kogan Page.

Gray, R., J. Bebbington & D. Walters (1993). *Accounting for the environment*. London: Paul Chapman Publishing Ltd. ISBN: 1-85396-223-6.

Griggs, S. (1987). Analysing qualitative data. *Journal of the Market Research Society* 29:1, 15–34.

Guide, D. (2000). Production planning and control remanufacturing: industry practice and research needs. *Journal of Operations Management* 18:4, 467–483.

Guide, D., V. Jayaraman, R. Srivastava & W. Benton (2000). Supply-chain management for recoverable manufacturing systems. *Interfaces* 30:3, 125–142.

Guide D. & R. Srivastava (1997). Repairable inventory theory: Models and applications. *European Journal of Operational Research* 102:1, 1–20.

Guide, V., M. Kraus & R. Srivastava (1997). Scheduling policies for remanufacturing. *International Journal of Production Economics* 48:2, 187–204.

Guide, D., R. Srivastava & M. Spencer (1997). An evaluation of capacity planning techniques in a remanufacturing environment. *International Journal of Production Research* 35:1, 67–82.

Guide, D. & L. van Wassenhove (2001). Managing product returns for remanufacturing. *Production and Operations Management* 10:2, 142–155.

Guide, D., V. Jayaraman & J. Linton (2003). Building contingency planning for closed-loop supply chains with product recovery. *Journal of Operations Management* 21:3, 259–279.

Gungor, A. & S. Gupta (1999). Issues in environmentally conscious manufacturing and product recovery: A survey. *Computers & Industrial Engineering* 36:4, 811–853.

Gungor, A. & S. Gupta (2002). Disassembly line in product recovery. *International Journal of Production Research* 40:11, 2569–2589.

Hammer, M. & J. Champy (1993). *Reengineering the corporation: a manifesto for business revolution*. London: HarperCollins. ASIN: 0887306403.

Handfield, R., S. Walton, L. Seegers & S. Melnyk (1997). Green value chain: practices in the furniture industry. *Journal of Operations Management* 15:4, 293–315.

Handfield, R. & E. Nichols (1999). *Introduction to Supply Chain Management*. NJ: Prentice-Hall, Englewood Cliffs. ISBN: 0136216161.

Harris, S. & R. Sutton (1986). Functions of parting ceremonies in dying organizations. *Academy of Management Journal* 29:1, 5–30.

Haug, H. (1990). Quality management should bring IBM into the lead again. *Stuttgart Newspaper* 7:December, 25.

Hayes, R. & D. Upton (1998). Operations-based strategy. *California Management review* 40:4, 8–25.

Helms, M. (2002). Reverse logistics. Available: http://www.daltonstate.edu/faculty/mhelms/citizen/2002_05_26.html.

Herberling, M. (1993). The rediscovery of modern purchasing. *International Journal of Purchasing and Materials Management* 29:4, 47–53.

Hill, R., M. Omar & D. Smith (1999). Stock replenishment policies for a stochastic exponentially declining demand process. *European Journal of Operational Research* 116:2, 374–388.

Hill, T. (1994) *Manufacturing Strategy*. R.D. Burr Ridge, IL: Irwin Publishing. ASIN: 0256106665.

Hillegersberg, J., R. Zuidwijk, J. Nunen & D. Eijk (2001). Supporting return flows in the supply chain. *Communications on the ACM* 44:6, 74–79.

Hofstede, G. (1994). *Cultures and Organizations; Software of the Mind. Intercultural Cooperation and its Importance for Survival.* Glasgow: Harper Collins Publishers. ISBN: 0006377408.

Hull, D. & J. Cox (1994). The field service function in the electronics industry: providing a link between customers and production/marketing. *International Journal of Production Economics* 37:1, 115–126.

Humphreys, P., R. McIvor & E. MvAleer (2000). Re-engineering the purchasing function. *European Journal of Purchasing & Supply Management* 6, 85–93.

Hwang, C. & K. Yoon (1981). *Multi Attribute Decision Making: Methods and Applications*. Berlin, Germany: Springer-Verlag.

Inderfurth, K., A. Kok & S. Flapper (2001). Product recovery in stochastic remanufacturing systems with multiple reuse options. *European Journal of Operational Research* 133:1, 130–152.

Inderfurth, K. & R. Teunter (2001). Production planning and control of closed-loop supply chains. *Econometric Institute Report EI 2001-39.*

Inoue, H. (1994). Designed for disassembly. *Look Japan*, November, 24–25.

Institute for Management Development. Available: http://www.imd.ch.

Jahre, M. (1995). Household waste collection as a reverse channel. A theoretical perspective. *International Journal of Physical Distribution & Logistics Management* 25:2, 39–55.

Jayaraman, V., R. Patterson & E. Rolland (2003). The design of reverse distribution networks: Models and solution procedures. *European Journal of Operational Research* 150:1, 128–149.

Johnson M. & M. Wang (1995). Planning product disassembly for material recovery opportunities. *International Journal of Production Research* 33:1, 3119-3142.

Kakabadse, N. & A. Kakabadse (2000). Critical review-outsourcing: A paradigm shift. *The Journal of Management Development* 19:8, 670–728.

Kaplan, B. & J. Maxwell (1993). Qualitative research methods for evaluating computer information systems. In *Evaluating Health Care Information Systems: Methods and Applications*, 45-68. London: J.G. Anderson, C.E. Aydin and S.J. Jay. Thousand Oaks, CA: Sage Publications. ISBN: 0803949367.

Kearney, A. (1994). Achieving customer satisfaction through logistics excellence. *Managing Service Quality* 4:2, 47–50.

Kekäle, T. (2001). Construction and triangulation: weaponry for attempts to create and test theory. *Management Decision* 39:7, 556–563.

Keough, M. (1994). Buying your way to the top. *Director* 47:9, 72-75.

Kitazawa Sh. & J. Sarkis (2000). The relationship between ISO 14001 and continuous source reduction programs. *International Journal of Operations & Production Management* 20:2, 225–248.

Kivinen, P. (2002).Value added logistical support service. Part 2. Outsourcing process of spare part logistics in metal industry. *Research Report 138*. Lappeenranta University of Technology, Department of Industrial Engineering and Management.

Klausner, M. & C. Hendrickson (2000). Reverse-logistics strategy for product take-back . *Interfaces* 30:3, 156–165.

Knecht, T., R. Lezinski & F. Weber (1993). Making profits after the sale. *The McKinsey Quarterly* 4, 79–86.

Knemeyer, A., T. Ponzurick & C. Logar (2002). A qualitative examination of factors affecting reverse logistics system for end-life computers. *International Journal of Physical Distribution & Logistics Management* 32:6, 455–479.

Kokkinaki, A., R. Dekker, M. de Koster & C. Pappis (Verbeke, W.) (2001). From e-trash to e-treasure: how value can be created by the new e-business models for reverse logistics. *Econometric Institute Report, 214*. Erasmus University Rotterdam, Econometric Institute.

Kolchin, M. & L. Giunipero (1993). *Purchasing Education and Training: Requirements and Resources*. Tempe, Arizona: Centre for Advanced Purchasing Studies.

Kopicki, R., M. Berg, L. Legg, V. Dasappa, V. & C. Maggioni (1993). *Reuse and recycling: reverse logistics opportunities*. Illinois: Council of Logistics Management, Oak Brook.

Korpela, J. & M. Tuominen (1996). A decision support system for strategic issues management of logistics. *International Journal of Production Economics* 46–47, 605–620.

Koster, R., M. Vendel & M. de Brito (2001). How to organize return handling: an exploratory study with nine retailer warehouses. *ERIM report series Research in Management*. September.

Krikke, H., A. Harten & P. Schuur (1998). On a medium term product recovery and disposal strategy for durable assembly products. *International Journal of Production Research* 36:1, 111–139.

Krikke, H., A. Harten & P. Schuur (1999). Business case Roteb: recovery strategies for monitors. *Computers and Industrial Engineering* 36:4, 739–757.

Krikke H., J. Bloemhof-R. & L. Wassenhove (2003). Concurrent product and closed-loop supply chain design with an application to refrigerators. *International Journal of Production Research* to appear in 2003.

Kroon L. & G. Vrijens (1995). Returnable containers: an example of reverse logistics. *International Journal of Physical Distribution & Logistics Management* 25:2, 56-68.

Krueger, R. (2000). *Focus Groups: A Practical Guide for Applied Research*. London: Sage Publications. ISBN: 0761920714.

Krulak, C. (1997). Marine Corps Doctrinal Publication (MCDP) 4, Logistics. Available: http://www.au.af.mil/au/awc/awcgate/mcdp4/fore.htm.

Krumwiede, D. & Ch. Sheu (2002). A model for reverse logistics entry by third-party providers. *Omega* 30:5, 325–333.

Krupp, J. (1992). Core obsolescence forecasting in remanufacturing. *Production and Inventory Management Journal* 33:2, 12–17.

Kyj, L. & M. Kyj (1994). Customer service: product differentiation in International Markets. *International Journal of Physical Distribution & Logistics Management* 24:4, 41–49.

Lalonde, B. & M. Cooper (1989). *Partnerships in Providing Customer Service: A Third Party Perspective*. Illinois: Council of Logistics Management.

Lamar, J. & D. Dobler (1995). *Purchasing and Material Management: Text and Cases*. 3 ed. New York: McGraw-Hill. ISBN: 0-07-037027-3.

Lambert, D. & M. Cooper (2000). Issues in supply chain management. *Industrial Marketing Management* 29:1, 65–83.

Lamming, R. & J. Hampson (1996). The environment as a supply chain management issue. *British Journal of Management* 7:Special Issue, S45–S62.

Lave, L. & C. Hendrickson (1999). Municipal solid waste recycling issues. *Journal of Environmental Engineering* 125:10, 944–949.

Lederman, L. (1989). Assessing educational effectiveness: the focus group interview as a technique for data collection. *Paper presented at the meeting of the Speech Communication Association*, San Francisco, CA.

Leenders, M., H. Fearon & W. England (1989). *Purchasing and Materials Management*, Boston, MA: Irwing.

Lele, M. (1986). How service needs influence production strategy?. *Sloan Management Review* 28:1, 63–70.

Lele, M. (1997). After-sales service-necessary evil or strategic opportunity? *Managing Service Quality* 7:3, 141–145.

Lele, M. & J. Sheth (1987). *The customer is the key: Gaining an Unbeatable Advantage Through Customer Satisfaction*. New York: John Wiley & Sons. ASIN: 0471828599.

Lele, M. & U. Karmarkar (1983). Good product support is smart marketing. *Harvard Business Review* 61:6, 124–132.

Leonard-Barton, D. (1988). Synergistic design for case studies: Longitudinal single-site and replicated multiple-site. *Proceedings of the National Science Foundation Conference on Longitudinal Research Methods in Organizations*, Austin.

Lewis, M. (1998). Iterative triangulations: A theory development process using case studies. *Journal of Operations Management* 16, 455–469.

Lieb, R. & H. Randall (1999). 1997 CEO perspectives on the current status and future of the third party logistics industry in the United States. *Transportation Journal* 38:3, 28–42.

Lippman, S. (2002). Environmental Responsibility: Are Corporations Buying It? A Look at Corporate Green Purchasing (Archive). Available: http://www.trilliuminvest.com/pages/news/news_detail.asp?ArticleID=163&Status=Archive.

Listes, O. & R. Dekker (2001). Stochastic approaches for product recovery network design: a case study. *Econometric Institute Report 2001-08*, Erasmus University Rotterdam, The Netherlands.

Loomba, A. (1996). Linkages between product distribution and service support functions. *International Journal of Physical Distribution & Logistics Management* 26:4, 4–22.

Louwers, D., B. Kip, E. Peters, F. Souren & S. Flapper (1999). A facility location allocation model for re-using carpet materials. *Computers & Industrial Engineering* 36:4, 1–15.

Lund, R. (1983). Remanufacturing, United States experience and implications for development nations. *MIT Centre for Policy Alternatives Report, CPA/83-17*, Cambridge, MA.

Lund, R. (1998). Remanufacturing: an American resource. *Proceedings of the 5th International Congress Environmentally Conscious Design and Manufacturing.* Rochester Institute of Technology, Rochester, NY, USA.

Madu, Ch., Ch. Kuei & I. Madu (2002). A hierarchic metric approach for integration of green issues in manufacturing: a paper recycling application. *Journal of Environmental Management* 64:3, 261–272.

Majumder, P. & H. Groenevelt. (2001). Competition in remanufacturing. *Production and Operations Management* 10:2, 125–141.

Mallen, B. (1996). Selecting channels of distribution: A multi-stage process. *International Journal of Physical Distribution & Logistics Management* 26:5, 5–21.

Maltz, A. (1994). Outsourcing the warehousing function: Economic and Strategic Considerations. *Logistics and Transportation Review* 30:3, 245–265.

Maslennikova I. & D. Foley (2000). Xerox's approach to sustainability. *Interfaces* 30:3, 226–233.

Mason, S. (2002). Backwards Progress, *IIE solutions* 34:8, 42–46.

McCutcheon, D. & J. Meredith (1993). Conducting case study research in operations management. *Journal of Operations Management* 11:3, 239–256.

Meade, L. & J. Sarkis (2002). A conceptual model for selecting and evaluating third-party reverse logistics providers. *Supply Chain Management: An International Journal* 7:5, 283–295.

Melbin, J. (1995). The never-ending cycle. *Distribution* 94:11, 36–38.

Melynk, S., R. Stroufe, F. Montabon, R. Calantone, R. Tumala & T. Hinds (1999). Integrating environmental issues into material planning: "green" MRP. *Production and Inventory Management Journal* 40:3, 36–45.

Mentzer, J. & K. Kahn (1995). A framework of logistics research. *Journal of Business Logistics* 16:1, 231–250.

Meredith, J. (1998). Building operations management theory through case and field research. *Journal of Operations Management* 16:4, 441–454.

Merton, R., M. Fiske & P. Kendall (1990). *The Focused Interview: A Manual of Problems and Procedures.* 2 ed. London: Collier MacMillan. ISBN: 0029209862.

Messner, W. (1982). Profitable Purchasing Management. *AMACOM*, June.

Meyer, H. (1999). Many happy returns. *The Journal of Business Strategy* 20:4, 27–31.

Miller, G. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *The Psychological Review*, 63, 81–97.

Min, H. & W. Galle (1997). Green Purchasing Strategies: Trends and Implications. *International Journal of Purchasing and Materials Management* Summer, 10–17.

Min, H. & W. Galle (2001). Green purchasing practices of US firms. *International Journal of Operations & Production Management* 21:9, 1222–1238.

Minahan, T. (1998). Manufacturers take aim at end of the supply chain. *Purchasing* 124:6, 111–112.

Moffat, J. (1992). Resources for the repair of non-modular aero-engines, *Omega-International of Management Science* 20:1, 99–103.

Montgomery, A., K. Manrodt & M. Holcomb (2002). Visibility: tactical solutions, strategic implications. *Report Cap Gemini Ernst & Young,* University of Tenessee and Georgia Southern University.

Morgan, D. (1997). *Focus Group as a Qualitative Research.* 2 ed. Beverly Hills: Sage Publications, Inc. ISBN: 0761903437.

Morgan, D. & M. Spanish (1984). Focus groups: a new tool for qualitative research. *Qualitative Sociology*, 7, 253–270.

Morganosky, M. & B. Cude (2000). Large format retailing in the US: a consumer experience perspective. *Journal of Retailing and Consumer Services* 7:4, 215–222.

Moyer, L. & S. Gupta (1997). Environmental concerns and recycling/disassembly efforts in the electronics industry. *Journal of Electronics Manufacturing* 7:1, 1–22.

Muffatto, M. & A. Payaro (2003) Implementation of e-procurement and e-fulfilment processes: A comparison of cases in the motorcycle industry. *International Journal of Production Economics*. Article in Press.

Murphy, P. (1986). A preliminary study of transportation and warehousing aspects of reverse distribution. *Transportation Journal* 25:4, 12–21.

Murphy, D. & M. Herbeling (1994). Purchasing strategies for environmental restoration projects. *International Journal of Physical Distribution & Logistics Management* 24:5, 45–55.

Murphy, P. & R. Poist (1989). Management of logistical retromovements: an empirical analysis of literature suggestions. *Transportations Research Forum*, 177–184.

Murphy, P. & R. Poist (2003). Green perspectives and practices: a "comparative logistics" study. *Supply Chain Management: An International Journal* 8:2, 122–131.

Murphy, P., R. Poist & Ch. Braunschwieg (1994). Management of environmental issues in logistics: Current status and future potential. *Transportation Journal* 34:1, 48–56.

Murray, J. & M. Kotabe (1999). Sourcing strategies of US service companies: a modified transaction-cost analysis. *Strategic Management Journal* 20:9, 791–809.

Murthy, D. & I. Djamaludin (2002). New product warranty: A literature review. *International Journal of Production Economics* 79:3, 231–260.

Newman, R. & M. Hanna (1996). An empirical exploration of the relationship between manufacturing strategy and environmental. *International Journal of Operations & Production Management* 16:4, 69–87.

O'Sullivan, D. (1997). Logistics in Europe: the vision and the reality. *Logistics Information Management* 10:1, 14–19.

OECD, Organization for Economic Cooperation and Development, 1997. Extended producer responsibility; Case study on German Packaging Ordinance. Paris.

Office of the Federal Environmental Executive. Available: http://www.ofee.gov/gp/gp.htm.

Overholser, C. (1986). Quality, quantity and thinking real hard. *Journal of Advertising Research* 26:3, 7–12.

Panisset, B. (1988). MRP II for repair/refurbish industries. *Production and Inventory Management Journal* 29:4, 12–15.

Parasuraman, A., V. Zeithaml & L. Berry (1988). SERVQUAL; A multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing* 64:1, 12–37.

Patton, M. (1986). *Utilization Focused Evaluation*. 2 ed. Newbury Park: CA. Sage Publishers. ISBN 0-8039-2566-2.

Pettigrew, A. (1988). Longitudinal field research on change: Theory and practice. *Proceedings of the National Science Foundation Conference on Longitudinal Research. Methods in Organizations*. Austin.

Pfohl, H. & B. Ester (1999). Benchmarking for spare parts logistics. *Benchmarking: An International Journal* 6:1, 22–39.

Phelan, M. (1996). Green is the colour of money for Dupont. *AI*, June, 93.

Philipp, B. (2000). La reverse logistics au sein des canaux de distribution inversée: les formes adéquates de coopération pou la chaîne logistique de valorisation des produits en fin de vie. *Proceedings of the Third International Meeting for Research in Logistics (IMRL)*. France.

Pilkington, A. (1998). Manufacturing strategy regained: evidence for the demise of best practice. *California Management Review* 41:1, 31–42.

Pohlen, T. & M. Farris (1992). Reverse logistics in plastics recycling. *International Journal of Physical Distribution & Logistics Management* 22:7, 35–47.

Porter, M. (1985). *Competitive Advantage: Creating and Sustaining Superior Performance*. New York: Free Press. ISBN: 0029250900.

Porter, M. (1998). *Competitive Strategy: Techniques for Analysing Industries and Competitors*. New York: Free Press. ISBN: 0684841487.

Porter, M. & C. van der Linde (1995). Green and competitive: ending the stalemate. *Harvard Business Review* 73:5, 120–137.

Purohit, D. (1992). Exploring the relationship between the markets for new and used durable goods: the case of automobiles. *Marketing Science* 11:2, 154–167.

Quinn, J. & F. Hilmer (1994). Strategic outsourcing. *Sloan Management Review* 35:4, 44–55.

Razaque, M.A. & Sheng, Ch.Ch. (1998). Outsourcing of logistics functions: a literature survey. *International Journal of Physical Distribution & Logistics Management* 28:2, 89–107.

Reisman, A. (1988). On alternative strategies for doing research in the management and social sciences. *Engineering Management, IEEE Transactions on* 35: 4, pp. 215-220.

Reverse Logistics Executive Council. Available: http://www.unr.edu/coba/ logis/ page6.html.

Revlog. European Working Group on Reverse. Available: http://www.fbk. eur.nl/OZ/REVLOG/.

Richardson, H. (2001). Logistics in reverse. *Industry Week* 250:6, 37–39.

Richter, K. (1996). The extended EOQ repair and waste disposal model. *International Journal of Production Economics* 45:1-3, 443–447.

Ritchie, L., B. Burnes, P. Whittle & R. Hey (2000). The benefits of reverse logistics: the case of Manchester Royal Infirmary Pharmacy. *Supply Chain Management: an International Journal* 5:5, 226–233.

RLEC. Reverse logistics Executive Council, 1999. Consumer electronics manufacturer survey. Available: http://www.rlec.org/elecsurvey.pdf.

Rogers, D., P. Larson & R. Tibben-Lembke (2001). E-commerce reverse logistics. Reverse Logistics Executive Council, March. Available: http://www.rlec.org/Memphis presentation.pdf.

Rogers, D. & R. Tibben-Lembke (1999). *Going Backwards: Reverse Logistics Trends and Practices*. Pittsburgh, P.A.: Reverse Logistics Executive Council.

Rondinelly, D. & M. Berry (2000). Environmental citizenship in multinational corporations: social responsibility and sustainable development. *European Management Journal* 18:1, 70–84.

Rudi, N., D. Pyke & P. Sporsheim (2000). Product recovery at the Norwegian National Insurance Administration. *Interfaces* 30:3, 166–179.

Russell, R. & B. Taylor (2002). *Operations Management.* 4 ed. Prentice Hall College Div. ISBN: 0130348341.

Saaty, T. (1980). *The Analytic Hierarchy Process*. USA: McGraw-Hill, Inc. ASIN: 0070543712.

Saaty, T. (1989). Group decision-making and the AHP. In: *The Analytic Hierarchy Process: Applications and Studies*, 59-67. Ed. B.L. Golden, E.A. Wasil, P.T. Harker. Springer, New York.

Saaty, T. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operations Research* 48, 9–26.

Saaty, T. (1994). How to make a decision: the analytic hierarchy process. *Interfaces* 24:6, 19–43.

Salomon, V. & J. Montevechi (2001). A compilation of comparisons on the analytic hierarchy process and others multiple criteria decision making methods: some cases developed in Brazil. *Proceedings of 6th ISAHP 2001*, Berne, Switzerland, 413–419.

Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner Production* 11:4, 397–409.

Sarkis, J., N. Darnall, G. Nehman & J. Priest (1995). The role of supply chain management within the industrial ecosystem. *Proceedings of the 1995 IEEE International Symposium on Electronics & the Environment*, Orlando, FL. 229–234.

Sarkis, J. & S. Talluri (2002). A model for strategic supplier selection. *Journal of Supply Chain Management* 38:1, 18–28.

Savaskan, C. (1999). Channel choice and coordination in remanufacturing environment. *Working paper series 99/14/TM INSEAD.*

Schary, P.B. (1992). A concept of customer service. *Logistics and Transportation Review* 28:4, 341–352.

Schell, R. (2003). La segunda oportunidad de los móviles. *Actualidad Económica* May-June, 88–89.

Schenkerman, S. (1997). Inducement of nonexistent order by the analytic hierarchy process. *Decision Sciences* 28:2, 475–482.

Shibuya, T., T. Dohi & S. Osaki (1999). Optimal continuous review policies for spare part provisioning with random lead times. *International Journal of Production Economics* 55:3, 257–271.

Schoemaker, P. & C. Waid (1982). An experimental comparison of different approaches to determining weights in additive utility models. *Management Science* 28, 182–196.

Schoner, B. & W. Wedley (1989). Ambiguous criteria weights in AHP: consequences and solutions. *Decision Sciences* 20:3, 462–475.

Shu, L. & W. Flowers (1995). Considering remanufacture and other End- of life Options in Selection of Fastening and Joining Methods. *IEEE International Symposium on Electronics & the Environment*. Orlando, FL. 75–80.

Smith, N., R. Thomas & J. Quelch (1997). A strategic approach to managing product recalls. *Journal of Product Innovation Management* 14:3, 228–229.

Skjoett-Larsen, T. (2000). European logistics beyond 2000. *International Journal of Physical Distribution & Logistics Management* 30:5, 377–387.

Soto, J. & H. Ramalhinho (2002). A recoverable production planning model. *Working Paper of Department in Economics & Business,* Universitat Pompeu Fabra, Barcelona (Spain).

Statistical Yearbook of Finland 2002 (2002). Vol. 37. Hämeenlina: Statistics Finland, ISBN: 952-467-071-2.

Stavros, E., P. Costas & G. Theodore (2003). Applying life cycle inventory to reverse supply chains: a case study of lead recovery from batteries. *Resources, Conservation and Recycling* 37:4, 251–281.

Sterling, J. & D. Lambert (1989). Customer service research: past, present and future. *International Journal of Physical Distribution & Logistics Management* 19:2, 3–23.

Stewart, D. & P. Shamdasani (1990). *Focus Groups: Theory and Practice.* London: Sage. ISBN: 0803933908.

Stock, J. (1992). *Reverse logistics*. Council of Logistics Management, Oak Brook, IL.

Stock, J. (1998). *Development and implementation of reverse logistics programs.* Council of Logistics Management. Oak Brook, IL.

Stock, J. (2001). The 7 deadly sins of reverse logistics. *MH Solutions* March, 5–11.

Sum, Ch. & Ch. Teo (1999). Strategic posture of logistics provides in Singapore. *International Journal of Physical Distribution & Logistics Management* 29:9, 588–605.

Sykes, W. (1991). Taking stock: issues from the literature on validity and reliability in qualitative research. *Journal of the Market Research Society*, 33:1, 3–12.

Tan, A. & A. Kumar (2003). Reverse logistics operations in the Asia-Pacific region conducted by Singapore based companies: an empirical study. *Conradi Research Review* 2:1, 25–48.

Tan, A., W. Yu & A. Ho (2001). Managing reverse logistics operations in Asia. *Proceedings of he First International Conference of Integrated Logistics*, 223–230.

Tan, A., W. Yu & A. Kumar (2003). Improving the performance of a computer company in supporting its reverse logistics operations in the Asia-Pacific region. *International Journal of Physical Distribution & Logistics Management* 33:1, 59–74.

Terry, S.H. (1869). *The Retailer's Manual*. Jennings Bros., Newark, N.J. reprinted by B. Earl Puckett Fund for Retail Education, Guinn, New York, NY (1967).

Thierry, M., M. Salomon, J. Nunnen & L. Wassenhove (1995). Strategic issues in Product Recovery Management. *California Management Review* 37:2, 114–135.

Thierry, M. (1997). An analysis of the impact of Product Recovery Management on manufacturing companies. *PhD. Thesis*, Erasmus University Rotterdam, The Netherlands.

Triantaphyllou, E. & A. Sánchez (1997). A sensitivity analysis approach for some deterministic multi-criteria decision making methods. *Decision Sciences* 28:1, 151–194.

Uusi-Rauva, E., M. Haverila & I. Kouri (1994). *Teollisuustalous*. Infacs Johtamistekniikka Oy. ISBN: 951-96765-0-3.

van Hoek, R. (1999). From reversed logistics to green supply chains. *Supply Chain Management* 4:3, 129–134.

van Hoek, R. & H. Commandeur (1998). Reconfiguring logistics systems through postponement strategies. *Journal of Business Logistics* 19:1, 33–54.

Veerakamolmal P. & S.M. Gupta (2000). Optimising the supply chain in reverse logistics. *Proceedings of the SPIE International Conference on Environmentally Conscious Manufacturing* 4193, 157–166.

Venkatraman, N. (1997). Beyond outsourcing: managing IT resources as a value centre. *Sloan Management Review* 38:3, 51–64.

Villalba, G., M. Segarra, A. Fernández, J. Chimenos & F. Espiell (2002). A proposal for quantifying the recyclability of materials. *Resources, Conservation and Recycling* 37:1, 39–53.

Voss, Ch., N. Tsikriktsis & M. Frhlich (2002). Case research in operations management. *International Journal of Operations & Production Management*. 22:2, 195–219.

Walker, W. (2000). Rethinking the reverse supply chain. *Supply Chain Management Review* May/June, 52.

Walley, N. & B. Whitehead (1994). It's not easy being green. *Harvard Business Review* 72:3, 46–52.

Walton, S., R. Handfield & S. Melnyk (1998). The green supply chain: integrating suppliers into environmental management process. *International Journal of Purchasing and Materials Management* 34:2, 2–11.

Wharton universia (2003). Proveedores de servicios outsourcing suben posiciones en la cadena de valor. October. Available: http://wharton.universia.net/.

Wasil, E. & B. Golden (2003). Celebrating 25 years of AHP-based decision-making. *Computers & Operations Research, Part Special Issue: Analytic Hierarchy Process* 30:10, 1419–1420.

Wassweiler, W. (1993). Know the MRPII fundamentals that support remanufacturing. *Manufacturing Systems* 11, 52–55.

Welch, J. (1985). Researching marketing problems and opportunities with focus groups. *Industrial Marketing Management* 14:4, 245–253.

Wells, W. (1974). *Group Interviewing. Handbook of Marketing Research.* McGrawHill Book Co. Inc.

White, Ch., E. Masanet, Ch. Rosen & S. Beckman (2003). Product recovery with some byte: an overview of management challenges and environmental consequences in reverse manufacturing for the computer industry. *Journal of Cleaner Production* 11:4, 445–458.

Wiendhal, H., B. Lorenz & S. Bürkner (1998). The necessity for flexible and modular structures in hybrid disassembly processes. *Production engineering* 5, 71–76.

Williamson, O. (1979). Transaction-cost economics: The governance of contractual relations. *Journal of Economic Issues* 22, 233–261.

Williamson, O. (1983). *Markets and Hierarchies: Analysis and Antitrust Implications.* Free Press. ASIN: 0029347807.

Winsemius, P. & U. Guntram (1992). Responding to the environmental challenge. *Business Horizons* 35:2, 12–20.

Witt, C. (1995). Distribution: A differentiator in 2000. *Material Handling Engineering* 50:11, 57–77.

Wright, L. (1996). Exploring the in-depth interview as a qualitative research technique with American and Japanese Firms. *Marketing Intelligence & Planning* 14:6, 59–65.

Wu, H. & S. Dunn (1995). Environmentally responsible logistics systems. *International Journal of Physical Distribution & Logistics Management* 25:2, 20–38.

Yin, R. (1984). *Case Study Research*. Beverly Hills, CA: Sage Publications.

Yin, R. (1989). *Case Study Research: Design and Methods*. Newbury Park, CA: Sage Publications.

Zanakis, S., A. Solomon, N. Wishart & S. Dublish (1998). Multi-attribute decision-making: A simulation comparison of select methods. *European Journal of Operational Research*. 107:3, 507–529.

Zeller, R. & E. Carmines (1980). *Measurement in the Social Sciences: The Link Between Theory and Data*. Cambridge: Cambridge University.

Zikmund, W. & W. Stanton (1971). Recycling solid wastes: a channels-of-distribution problem. *Journal of Marketing* 35:3, 34–39.

Zsidisin, G. & S. Siferd (2001). Environmental purchasing: a framework for theory development. *European Journal of Purchasing & Supply Management* 7:1, 61–73.

APPENDICES

Appendix 1. Brief History of Operations Management. Adapted from Russell & Taylor (2002)

STAGE		TIME	PERSON
Industrial Revolution			
✓ Steam engine		1769	James Watt
✓ Division of labour		1776	Adam Smith
✓ Interchangeable parts		1790	Eli Whitney
Scientific Management School			
✓ The Principles of Scientific Management		1911	Frederick W. Taylor
✓ Time / motion study		1911	Frank & Lillian Gilbreth
✓ Scientific management techniques in factories		1913	Henry Ford
✓ Activity scheduling chart		1914	Henry Gant
Human Relations School			
✓ Hawthorne studies		1930	Elton Mayo
✓ Motivation theories	Motivational theories	1940's	Abraham Maslow
		1950's	Frederick Hertzberg
	Theory X and Theory Y	1960's	Douglas McGregor
	Theory Z	1970s	William Ouchi
Management Science			
✓ Linear programming		1947	George Dantzig
✓ Digital computer		1951	Remington Rand
✓ Simulation, PERT/CPM		1960	Research groups
✓ Queuing theory			
✓ Materials Requirement Planning (MRP)		1960's	Joseph Orlicky, IBM
Quality Revolution			
✓ Just In Time (JIT)		1970's	Taichi Ohno, Toyota
✓ Total Quality Management (TQM)		1980's	W. Edwards Deming Joseph Juran *et al.*
✓ Reengineering		1990's	Hammer &Champy (1993)
Information Age			
✓ E Data Interchange (EDI), EFT		1970's	Numerous individuals and companies
✓ Computer integrated manufacturing (CIM)		1980's	
✓ Artificial Intelligence (AI)		1990's	
✓ Internet			Tim Berners-Lee
Globalization			
✓ Worldwide markets		1990's	Numerous individuals and companies
✓ Supply chain management			
✓ Electronic commerce			
✓ Mass customization			

Appendix 2. Summary of references related to methodology, recovery options and reverse logistics.

METHODOLOGICAL

TYPE OF METHODOLOGY *Qualitative research (in general)*

AUTHOR(S)	APPROACH	FIELD
Axelrod M. (1975)	Methodological	
Glaser B. & Strauss A. (1999)	Methodological	
Goodyear M. (1990)	Methodological	
Griggs S. (1987)	Methodological	
Overholser C. (1986)	Methodological	
Patton M. (1986).	Methodological	
Reisman A. (1988)	Methodological	
Sykes W. (1991)	Methodological	
Kaplan B. & J. Maxwell (1993)	Empirical	Information systems
Wright L. (1996)	Empirical	Marketing

TYPE OF METHODOLOGY *Focus group*

AUTHOR(S)	APPROACH	FIELD
Byers P. & Wilcox J. (1991)	Methodological	
Calder B. (1977)	Methodological	
Fern E. (1982)	Methodological	
Goldman A. (1962)	Methodological	
Krueger R. (2000)	Methodological	
Lederman L. (1989)	Methodological	
Merton *et al.* (1990)	Methodological	
Morgan D. (1997)	Methodological	
Morgan D. & M. Spanish (1984)	Methodological	
Stewart D. & P. Shamdasani (1990)	Methodological	
Cox *et al.* (1976)	Empirical	Marketing
Welch J. (1985)	Empirical	Marketing
Wells W. (1974)	Methodology and application	Marketing

TYPE OF METHODOLOGY *Case and field research*

AUTHOR(S)	APPROACH	FIELD
Andersen *et al.* (1995)	Methodological	
Campbell D. (1975)	Methodological	
Dyer W. & Wilkins A. (1991)	Methodological	
Eisenhardt K. (1989)	Methodological	
Eisenhardt K. (1991)	Methodological	
Ellram L. (1996)	Methodological	
Leonard-Barton D. (1988)	Methodological	
Lewis M.W. (1998)	Methodological	
Yin R. (1984)	Methodological	
Yin R. (1989)	Methodological	
McCutcheon D. & Meredith J. (1993)	Methodology and application	Operations Management
Meredith J. (1998)	Methodology and application	Operations Management
Pettigrew A. (1988)	Methodology and application	Strategy
Voss *et al.* (2002)	Methodology and application	Operations Management

TYPE OF METHODOLOGY *Multi-attribute decision making methods*

GENERAL

Bana e Costa C.A. & Vansnick J.C. (1994)	Methodological	MACBETH
Benayoun *et al.* (1966)	Methodological	ELECTRE
Triantaphyllou E. & Sánchez A. (1997)	Methodological	Sensitivity analysis
Zanakis *et al.*(1998)	Methodological	ELECTRE, TOPSIS, MEW, SAW, AHP
Hwang C. & Yoon K. (1981)	Metodology and application	Economic systems

AHP

Bodin L. & Gass S.I. (2003)	Methodological	
Dyer J.S. (1990)	Methodological	
Forman E. & K. Peniwati (1998)	Methodological	
Saaty T. (1980)	Methodological	
Saaty T. (1989)	Methodological	
Saaty T. (1990)	Methodological	
Saaty T. (1994)	Methodological	
Schenkerman S. (1997)	Methodological	
Schoemaker P. & C. Waid (1982)	Methodological	
Schoner B. & W. Wedley (1989)	Methodological	
Wasil E. & B. Golden (2003)	Review	
Korpela J. & M. Tuominen (1996)	Empirical	Logistics
Salomon V. & J. Montevechi (2001)	Methodology and application	Fast food chains

ANP		
Sarkis J. & Talluri S. (2002)	Methodology and application	Supplier selection
Sarkis J. (2003)	Methodology and application	Green supply chain management

OPTION FOCUSED

TYPE OF FOCUS: ***RETURNS IN GENERAL***

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Brockmann T. (1999)	theoretical work	warehousing (trends)	journalistic
Carter C.R. & Ellram L.M. (1998)	model	strategy	review
Daugherty *et al.* (2002)	theoretical work		interviews/survey
de Brito *et al.* (2002)	theoretical work		review
Dowlatshahi S. (2000)	theoretical work	strategic/operational	review
Ferrer G. & Whybark C. (2001b)	theoretical work		
Fleischman *et al.* (2000)	theoretical work	network design	review
Fleischman *et al.* (1997)	theoretical work	inventory control, distribution planning and production	review
Fleischmann *et al.* (2001)	model	facility location	MILP
Giuntini R. & Andel T. (1995)	theoretical work		jounalistic
Giuntini R. & Andel T. (1995)	theoretical work		jounalistic
Guide *et al.* (2000)	theoretical work		
Güngör A. & Gupta S.M. (1999)	theoretical work		review
Helms M.M. (2002)	theoretical work		
Hillegersberg *et al.* (2001)	theoretical work	strategic/operational	
Koster *et al.* (2001)	theoretical work	network design	case study
de Koster *et al.* (2002)			
Lambert D. & Cooper M.	theoretical work		
Mason S. (2002)	theoretical work		journalistic
Meyer H. (1999)	theoretical work		review
Richardson H.L. (2001)	theoretical work		
Rogers D.S. & Tibben-Lembke R.S. (1999)	theoretical work		survey
Rogers D.S. & Tibben-Lembke R.S. (2001)	theoretical work	trend analysis	survey
Skjoett-Larsen T. (2000)	theoretical work	strategy	
Soto J.P.& Ramalhinho H. (2002)	model	production planning	simulation//optimization
Stock J.R. (2001)	theoretical work	strategy	
Tan A. & Kumar A. (2003)			survey
Thierry *et al.* (1995)	theoretical work	strategy	case study
Tibben-Lembke R.S. (2002)	theoretical work	strategy	LC
Tibben-Lembke R.S. & Rogers D.S. (2002)	theoretical work		differences

TYPE OF FOCUS: ***DISASSEMBLY***

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Brennan *et al.* (1994)		operations planning	
Güngör A. & Gupta S.M. (2002)	model[59]	operational	simulation/optimization
Johnson M. & Wang M.H. (1995)	model	operational	simulation/optimization
Krikke *et al.* (1998)	model	operational	optimization, case study
Tang *et al.* (2003)	model	operations planning, costs	
Teunter R.	model	inventory management	simulation/optimization
Veerakamolmal P.& Gupta S.M. (2000)	model	inventory management	simulation/optimization

TYPE OF FOCUS: ***SERVICE***

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Blumberg D.F. (1999)	theoretical work	strategy	survey
Botter R. & Fortuin L (2000)	model	inventory management	case study
Dawe R. (1995)	theoretical work	warehousing	
Emerson C.J. & Grimm C.M. (1996)		interfunctional coordination strategy	survey
Fortuin L. & Martin H. (1999)	theoretical work	inventory management	review of cases
Goffin K. (1999)	theoretical work	distribution channel	case study
Kearney A.T. (1994)		dimensions of excellent logistics	survey
Kivinen P. (2002)			
Kyj L. & Kyj M. (1994)	theoretical work	strategy	survey
Lele M.M. (1986)	theoretical work	strategy	
Lele M.M. (1997)	theoretical work		
Loomba A. (1996)	theoretical work		case study
Murthy D. N. P. & Djamaludin I. (2002)	theoretical work		
Pfohl H.C. & Ester B. (1999)		benchmarking	survey
Phelan *et al.* (2000)			
Sum Ch. & Teo Ch. (1999)	theoretical work	strategy: outsourcing	survey
Tan *et al.*, (2003)	theoretical work	strategy: reengineering	case study

[59] "Model" refers whether to theoretical o mathematical model.

TYPE OF FOCUS: *REPAIR*

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Ashayeri *et al.* (1999)	model	inventory management	case study
Brimer R.C. (1995)	theoretical work		journalistic
Dunn S. (1999)	theoretical work	strategy	
Guide D. & Shrivastava R. (1997)	model	inventory management	simulation/optimization
Panisset B.D. (1988)	theoretical work	inventory management	case study
Richter K. (1996)	model	inventory management	simulation/optimization

TYPE OF FOCUS: *REFURBISH*

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Jayaraman *et al.* (2003)	model	distribution networks	heuristics
Rudi *et al.* (2000)	model	operational	case study

TYPE OF FOCUS: *REMANUFACTURING*

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Ferrer G. & Ayres R.U. (2000)	theoretical work		INPUT-OUTPUT
Ferrer G. & Whybark C. (2000)	theoretical work		
Ferrer G. & Whybark C. (2001)	model	inventory management	simulation/optimization
Guide D. (2000)	theoretical work	production planning	survey
Guide *et al.* (1997)	model	operational: capacity planning	simulation/optimization
Guide *et al.* (1997)	model	operational: scheduling	ANOVA
Guide D. & van Wassenhove L.N. (2001)	model	operational	Economic Value Analysis
Inderfurth *et al.* (2001)	model	inventory management	simulation/optimization
Klausner M. & Hendrickson C.T. (2000)	model	take-back policy	simulation/optimization
Krupp J. (1992)	model	operational	valuation
Majumder P. & Groenevelt H. (2001)	model	strategy	Games Theory
Savaskan R. C. (1999)	model	distribution network	
Shu L.H. & Flowers W.C. (1995)	theoretical work	strategy	case study
White *et al.* (2003)	theoretical work		case study

TYPE OF FOCUS: *RECYCLING*

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Bellmann K. & Kahre A. (2000)	theoretical work		economic issues
Biddle D. (1993)	theoretical work	strategy	journalistic
Cairncross F. (1992)	theoretical work	strategy	journalistic
de Ron Ad & Penev K. (1995)	model	operational	DSS
Ginter P. & Starling J. (1978)		distribution channel	
Goldsby T.J. & Closs D.J. (2000)	theoretical work		case study
Knemeyer *et al.* (2002)	theoretical work	strategic/operational	qualitative
Krikke *et al.* (1999)	theoretical work	strategy	simulation/optimization
Listes O. & Dekker R. (2001)	model	network design	simulation/optimization
Liu *et al.* (2002)	model	strategy	Artificial Neural Networks, case study
Pohlen T.L. & Farris M.T. (1992)	theoretical work		survey
Ritchie *et al.* (2000)	theoretical work		case study
Stavros *et al.* (2003)	model	inventory management	case study
Villalba *et al.* (2002)	model	operational	

TYPE OF FOCUS: *ENVIRONMENTAL ISSUES*

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Angell L. C. & Klassen R.D. (1999)			
Azzone G. & Noci G. (1998)			
Azzone G. & Noci G. (1998)	model	strategy	
Elkington J. (1994)	theoretical work	strategy	case study
Handfield *et al.* (1997)	theoretical work	operational	case study
Kitazawa Sh. & Sarkis J. (2000)	theoretical work	strategy	case study
Maslennikova I. & Foley D. (2000)	theoretical work	strategy	case study
Meade L. & Sarkis J. (1998)	theoretical work	Logistics strategy assesment	ANP
Melynk *et al.* (1999)	theoretical work	operational	case study
Newman W. R. & Hanna M.D. (1996)	theoretical work	strategy	
Rondinelly D. & Berry M.	theoretical work	strategy	
Sarkis *et al.* (1995)	theoretical work	strategy	
Walley N. & Whitehead B. (1994)	theoretical work		

WITH PURCHASING			
Bowen *et al.* (2001)	theoretical work	strategy	survey
Drumwright M. (1994)	theoretical work		case study
Handfield *et al.* (2002)			AHP, pilot tests
Lamming R. & Hampson, J. (1996)	theoretical work	strategy	case study
Min H. & Galle W.P. (2001)	theoretical work	strategy	survey
Muffatto M. & Payaro A. (2003)	theoretical work		case study
Murphy D. & Herbeling M. (1994)	theoretical work		
Walton *et al.* (1998)	theoretical work		survey
Zsidisin G. & S. Siferd (2001)	theoretical work		

WITH LOGISTICS			
Ayres *et al.* (1997)	theoretical work	strategy	case study
Goldsby T. & T. Stank (2000)	theoretical work		review
Murphy *et al.* (1994)	theoretical work		survey
Murphy P.R.& Poist R.F. (2003)	theoretical work		survey
van Hoek (1999)	theoretical work	strategy	
Wu H-J. & Dunn S.C. (1995)	theoretical work		

TYPE OF FOCUS: ***WASTE MANAGEMENT***

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
Bossink B. A. & Brouwers H. J. (1996)	theoretical work		review
Jahre M. (1995)	theoretical work	operational	survey
Lave L.B.& Hendrickson C.T. (1999)	theoretical work	operational	review

TYPE OF FOCUS: ***OTHERS***

AUTOR	FRAMEWORK	STRATEGIC/ OPERATIONAL	METHODOLOGY
RECALLS			
Murphy, P. (1986)	theoretical work	Transportation and warehousing	survey
RESUSE			
Bloemhof-R. *et al.* (2001)	model		evaluation
Giuntini R. & Andel T. (1994)	theoretical work	operational	jounalistic
Kroon L. & Vrijens G. (1995)	theoretical work	network design	case study
SECONDARY MARKETS			
Purohit D. (1992)	theoretical work	strategy	regresion
CANNIBALIZATION			
Fleischmann *et al.* (2002)	model	inventory control, channel design	simulation/optimization