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The Reverse Supply Chain: Configuration, Integration and Profitability
Considerations Derived from a Qualitative Case Study Investigation

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The Reverse Supply Chain: Configuration, Integration and Profitability

Considerations Derived from a

Qualitative Case Study Investigation

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Department of Management Engineering

Ph.D. Dissertation

Title: The Reverse Supply Chain: configuration, integration and profitability

To my grandparents,
sure that they are smiling together in eternity

Abstract

This thesis presents the results of a qualitative investigation that has been conducted in order to enhance knowledge of the reverse supply chain management field.

Two aspects of the reverse flow need to be taken into consideration: the importance of introducing mechanisms that promote the circuitry of resources in order to protect the environment, and the increasing awareness that if strategically managed, the reverse chain represents an opportunity for profit generation and for improving the competitive position of a firm.

In the first case, the main stakeholders are represented by organisations and communities that are concerned about the deteriorating conditions of the environment, depletion of non-renewable resources, and ever increasing disposal of waste. These concerns find an answer in the approval of environmental legislations, introduced by governments in particular, in Europe, by the European Community. The number and scope of these regulations are due to increase over time as well as the impact they have on companies. This study has particularly considered the implementation of the reverse chain that aims at recovering electrical and electronic goods, complying with the European Directive for Waste of Electrical and Electronic Equipment (WEEE). The electrical and electronic waste represents on average 4% of the total disposed waste in Europe but it is extremely dangerous for the environment due to the materials content; furthermore, the disposing rate has increased every year within the 27 Member States, reaching approximately 14-24 Kg. per inhabitant in Western Europe and the 6-12 Kg. per inhabitant in the New Member States.

In the second case, the main stakeholder is the firm, the producer that has the possibility of exploring new opportunities to achieve a competitive advantage and generate profit by reconditioning and remarketing used products. Many different flows arise in this context: commercial returns, returns for repair, for refurbishment and for remanufacturing. This study has considered two instances of a value driven reverse chain that recondition electronic products, and represent an opportunity for profit generation for the producer and other involved service providers.

By confronting these two reverse chains (the first that has legislation as its distinctive driver, and the second that has value creation as main driver), the study presents the results of an analysis of three main aspects of the reverse chain: configuration, integration and profitability. Configuration is defined as how to configure and structure the chain in order to efficiently support the most proper recovery option: the elements that impact the chain design have been identified, and indications in order to manage them have been provided.

The argument for integration would be that by integrating the forward and reverse chain, different forms of efficiency would be guaranteed. The study provides a frame to evaluate the level of integration and contribute to explain why integration is in general not present.

Finally, the analysis around the profitability issue aims at providing indications to identify when and why the reverse chain is profitable and for whom. Furthermore, findings are interpreted in the light of two main theories: transaction costs economic theory and institutional theory.

Dansk resume: Forsyningskæden for retursystemer: konfigurering, integration og profitabilitet - resultater fra kvalitative casestudier

Denne afhandling dokumenterer en kvalitativ undersøgelse udført for at udvikle viden om retursystemer.

To aspekter af retursystemet er taget op til vurdering: vigtigheden af at introducere mekanismerne, der fremmer recirkulation af ressourcer for at beskytte miljøet, og for det andet; hvis det er strategisk korrekt forvaltet, repræsenterer retursystemet en mulighed for at profitere og øge en virksomheds konkurrenceevne.

I det første tilfælde, er hovedinteressenten repræsenteret ved organisationer og samfundsgrupper, som er bekymret for forringelsen af miljøets tilstand, udtømning af ressourcer der ikke kan gendannes, samt en konstant øgning i mængden af affald. Disse bekymringer adresseres gennem miljølovgivningen indført af regeringer på basis af udspil fra den Europæiske Union. Disse bestemmelser er øget over tid, og har en væsentlig betydning for virksomhederne.

Undersøgelsen har især analyseret den implementering af retursystemet, der har til formål, at genanvende elektriske og elektroniske produkter for at efterleve The European Directive for Waste of Electric and Electronic Equipment (WEEE). Det elektriske og elektroniske affald udgør et gennemsnit på 4 % af den totale mængde affald i Europa, men det er særdeles farligt for miljøet på grund af materialets indhold. Ydermere øges affaldsmængden hvert år indenfor de 27 medlemslande, der er på henholdsvis ca. 14-24 kg pr. indbygger i Vesteuropa og 6-12 kg pr. indbygger i de nye medlemslande.

I det andet tilfælde er hovedinteressenten producenten der har mulighederne for at udforske nye muligheder for at nå en konkurrencemæssig fordel, og indbringe en fortjeneste ved at renovere og genbruge produkter. Der er mange forskellige returstrømme i denne forbindelse: kommercielle returstrømme, returvarer til reparation, returvarer til renovering og til genfremstilling. To eksempler er analyseret i denne undersøgelse. De viser en mulighed for fortjeneste for producenten og andre involverede servicevirksomheder.

Ved at sammenholde disse to retursystemer, drives den ene af lovgivning og den anden af værdiskabelse. Analysen omfatter tre centrale aspekter ved returkæden: Konfiguration, integration og fortjeneste.

Med konfiguration menes hvordan retursystemet udformes og struktureres for effektivt at støtte den bedste genanvendelsesmulighed: Elementerne der påvirker design af kæden er identificeret, og der er givet indikationer for, hvordan de skal forvaltes.

Ved at integrere returkæden med den fremadrettede forsyningskæde vil forskellige former for effektivitetsgevinst kunne opnås.

Undersøgelsen giver en ramme for at evaluere niveauet af samkøring, og bidrager til at forklare hvorfor samkøring generelt ikke er til stede.

Endelig sigter analysen omkring rentabilitetsspørgsmålet efter at give indikatorer til at klarlægge hvornår, hvorfor og for hvem retursystemet er rentabelt. Endvidere er resultaterne tolket i lyset at to hovedteorier: transaktionsomkostninger og institutionel teori.

Acknowledgments

This thesis is submitted in candidacy for the PhD degree in Industrial Management at the Technical University of Denmark and describes the work I carried out under the supervision of Prof. Per Langaa Jensen from DTU Management, Department of Management Engineering.

I am deeply grateful to my supervisor for the support, inspiration, and guidance I received along the entire research project. I really appreciated his encouragement during the hard moments of the research journey, when disappointment risked ruining all the efforts and results accomplished. I also owe him further thanks for the patience and for always keeping faith in the successful outcome of the project, particularly when I had doubts.

I would also like to thank all the members of the Department of Management Engineering, the secretary Kirstine Lautrup and the staff personnel; a particular thank goes to Prof. Martin Grunow for always being helpful whenever I asked for his advice and support.

I am also very grateful to Prof. Arni Halldorsson of the School of Management, University of Southampton for the nice discussions I had with him during the entire project and his precious advice to always persevere with a clear focus on the main research issues.

I would also like to thank Prof. Enrico Cagno of the Politecnico of Milan for having introduced me to the world of the Italian recovery system and the opportunity to gather useful information and insights for my project during the study period abroad.

I am grateful to all the PhD students and researchers with whom I shared the office in Italy, for the nice and really welcoming atmosphere and the peer PhD students at the Department of Management Engineering, especially Dr. Sara Grex and Ph Dr. Christine Ipsen. Finally, I want to thank my family and all my friends in Italy and Copenhagen for their support and for being enormously patient especially during the writing period. A special thank to my closest friend Riccardo and to Paolo Spoladore.

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Chiara Gobbi
Lyngby, March 2008

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Terminology and abbreviations

B2B: Business to Business

B2C: Business to Consumers

EEE: Electrical and Electronic Equipment

LDRC: legislation driven reverse chain

DfR: Design for Recycling, Design for Remanufacturing

DfD: Design for Disassembly

DfX: Design for X techniques (Recycling, Remanufacturing, Disassembly)

EoL – End of Life products

EoU – End of Use products

LDRV: legislation driven reverse chain

MVT: Marginal value of time

OEM: Original Equipment Manufacturer

VDRC-I.1: value driven reverse chain, instance 1

VDRC-I.2: value driven reverse chain, instance 2

WEEE: Waste of Electrical and Electronic Equipment

Chapter 1. The Research Problem and Questions

"Only the knowledge that
makes us better is useful"
Socrates

1.1 Introduction

The deteriorating conditions of the environment, depletion of non-renewable resources, and the ever increasing disposal of waste have forced organisations and communities to consider recovery alternatives such as reuse, remanufacturing and recycling, rather than products discharging. In order to support the recovery process, the basic configuration of the entire logistics chain needs to be redefined so that related environmental concerns can be accommodated. Although European and national legislations are increasing awareness, the final aim should be the reutilisation of resources and therefore the integration of the delivery and recovery chains.

While historically firms have concentrated on getting products and services to the market and the amount of scientific contributions as well as business practices for the delivery chain are largely explored, relatively few contributions explore the potential of the reverse flow from a holistic point of view. Whilst concepts as bullwhip effect, just-in time, lean production, mass customisation, delayed product differentiation have been extensively explored both from a theoretical and operational point of view, few attempts to re-deploy the same body of knowledge to investigate the reverse chain are encountered in literature. In evaluating reverse logistics tasks, the focus has traditionally been in minimising costs ensuring a reasonable customer service. Over time, the recognition of the increasing value of products and technology created in the field at the end of the direct supply chain and the impact of the environmental legislation has

started to move companies' focus to different types of recovery programs, not merely centered on customer service. Recovering parts for repair, refurbishment, reconditioning and remarketing, recycling raw materials are all examples of reverse flows which represent an attractive business opportunity and a positive answer to sustainable development. Already in 1997, Andel stated: "…by ignoring the efficient return and refurbishment or disposal of product, many companies miss out a significant return on investment".

Therefore, two fundamental observations emerge: if environmental considerations are relevant for the forward chain, they become predominant in the reverse chain, to the point that in some situations the reverse flow is specifically initiated, structured and monitored by environmental regulations. Secondly, there is an increasing awareness that "reverse", if strategically considered, can provide a competitive advantage by consolidating market position, generating profit, tapping into alternative sources of raw materials, with the overall benefit of improving the company image.

Finally, as Socrates said "only the knowledge that makes us better is useful", we hope that this thesis by contributing to the development of the research field, also adds to the social debate of the importance of valuing the environment preservation.

1.2 The Research Problem

This thesis stemmed from two basic considerations:

- The increasing importance of protecting the environment and the increasing number of environmental regulations which force producers to take responsibility of the recovery process;

- The possibility of considering reverse initiatives and take back programs not only as an opportunity for costs reduction for landfill, incineration and energy consumption, but rather as a viable opportunity for profit generation.

Environmental legislations introduce the concept of extended producer responsibility and suggest recovery options and recovery targets. Priority is given to the recovery options of reuse and remanufacturing (

Figure **1**).
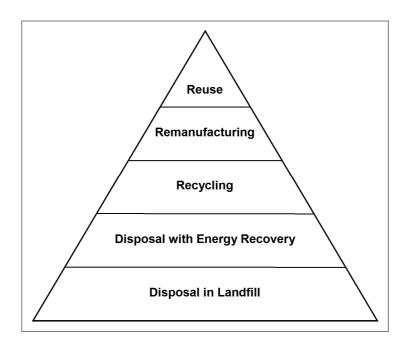
Figure 1 – Hierarchy of waste treatment options (Steven M. 2004).

While differences exist in the financing and implementation mechanisms, all environmental legislations introduced worldwide aim at reducing waste disposal, remove hazardous substances and impose minimum recycling targets.

However, both legislation and most of the existing literature are deficient in analysing:

- To which extent the reverse chain differs from the forward delivery chain;

- Which factors are essential in designing and configuring the recovery chain;

- If integration between the recovery management process and the forward flow is preferable and possible, in which conditions and for what reasons.

Besides, the possibility of considering "reverse" not anymore as pure cost but an opportunity for profit generation is emerging, not without difficulties.

In order to address the previous considerations, the research project has been organised around three research blocks as follows:

- Research question 1 interrogates for factors that should be considered when configuring the reverse chain.

- Research question 2 addresses the issue of integration between the reverse and the forward chain.

- Research question 3 examines the conditions for a profitable reverse flow.

In the next sections, we provide further motivations for supporting each of the three research questions, as well as how they are related.

1.2.1 The First Research Question: The Reserve Supply Chain Configuration

The literature on reverse supply chain lacks in providing guidelines for identifying the "right" reverse supply chain structure. By observing several settings of reverse chains and reverse supply chain implementation processes, it emerges the need to provide a grounded framework to identify and implement the right reverse supply chain. But "right" according to what? In 1997, Fisher proposed to analyse the product demand pattern in order to determine the right supply chain. He raised the observation that the demand pattern makes products essentially innovative or functional concluding that for functional products, the demand is predictable therefore the supply chain has to be efficient (supplying the demand at the lowest possible costs). Vice versa, when a product is innovative and the demand is unpredictable, the supply chain has to be responsive in order to minimise stockouts, markdowns and obsolescence which reduce customer service and loyalty.

Is it possible to elaborate similar evaluations in the case of the reverse supply chain? In the case of the reverse chain, the residual value of the disposed product plays a central role. The product residual value has to be taken into consideration when determining the appropriate recovery option, and therefore which reverse supply chain structure should be implemented. Or rather, it is not correct to convey products with low residual value to recovery options as refurbishment or remanufacturing. Therefore, the reverse chain has to be configured in order to support other sorts of recovery options like recycling or disposal. These considerations are summarised in Figure 2: the product residual value influences the choice of the recovery option that allows recapturing most of the value, and the recovery option influences the decisions related to the configuration of the reverse supply chain.

```
┌──────────────────┐     ┌──────────────┐     ┌──────────────────────┐
│ Product Residual │ →   │  Recovery    │ →   │   Reverse Supply     │
│      Value       │     │   Option     │     │ Chain Configuration  │
└──────────────────┘     └──────────────┘     └──────────────────────┘
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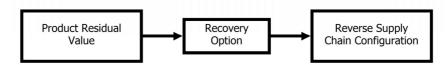
Figure 2 – The relation between the product residual value, the recovery option and the reverse supply chain configuration.

We assume that in configuring the reverse supply chain, it is primarily relevant to identifying the recovery option that better supports the process of product residual value recovering. Propositions 1 and 2 explicate the relation between the product residual value and the recovery option, the recovery option and the reserve chain configuration.

- ▪ Proposition 1. The product residual value determines the recovery option (repair, refurbishing, remanufacturing, and recycling): we can suppose that the higher the product residual value is, the higher the chance that the product can be refurbished and remarketed.

- ▪ Proposition 2. The recovery option determines the reverse chain structure, actors involved, configuration and relationships.

Therefore, ultimately, in order to determine the right reverse supply chain configuration it is necessary to evaluate the product residual value.

A concept similar to the product residual value, the marginal value of time, was adopted by Blackburn et al. 2004 to analyse the flow of commercial returns (products returned by customers up to 90 days after sale). The authors underlined that for time sensitive products as commercial returns, the speed at which products are received, inspected, refurbished and remarketed is particularly crucial in order to recapture most of the value. Commercial returns represent one portion of the total amount of returned products and large variations exist according to status, typologies and conditions. Is the processing time so relevant for other recovery options such as remanufacturing, refurbishing, repair and recycling? The cases presented in this project show that the processing time is mainly relevant for recovery options that aim at reconditioning the product, and less in case of components or materials recycling where other factors become more crucial, i.e., the process efficiency.

1.2.2 The Second Research Question: The Integration Between the Reverse and Forward Chain

Another objective of the thesis is contributing to the understating of differences and similarities between the forward and reverse supply chain by analysing different forms of product value recovery chains. Differences would lead to difficulties in integrating the reverse and the forward flows while similarities would lead to integration and synergies. Obviously, whenever possible, synergies are preferable since they can provide different forms of efficiency. Synergies can manifest at several levels: strategic, tactical and operational. From a strategic point of view, reverse and forward flows rarely share the same goals, nevertheless, at tactical and operational level, some forms of integration would be foreseeable. However, what happens in reality? Are forward and reverse flows integrated? Which factors allow the integration? And why integration is so important besides calling for synergies?

Integration is a much stressed element in all recent supply chain management literature, considered the primary component the supply chain has to develop and maintain in order to strength its competing ability. Integration is often synonymous of collaboration,

cooperation, information sharing, proactive instead of reactive response to market fluctuations, efficient inventory utilization, collaborative product development, and many other initiatives which promote an integrative approach to activities and processes performed in order to deliver a product to the market.

But a preliminary question would be: why should companies operate in supply chains? Literature and practice have proven the supply chain management approach to provide several advantages (Davis, 1993; Cooper et al., 1997). In 1991, Ellram interpreted supply chains as new way of competing in markets which are international, and subjected to continuous changes and pressure. The intense competition changes the level of confrontation: it is not longer company against company, but supply chains against supply chains, or taken to the limit, supply networks against supply networks (Cooper et al., 1997). To which extent a company should integrate with other supply chain partners (both in number and intensity of the relationship) is an element of discussion which depends on the many different contingent situations and overall strategic considerations. In any case, integration is present. And if supply chain management is such a winning approach, we don't have doubts that the same approach should be promoted in the case of reverse flows and that integration between the reverse and forward flows should also be preferable.

The closest concept to reverse and forward supply chain integration is mentioned in literature as looping supply chains (Geyer and Jackson, 2004; Krikke et al., 2004; Guide et al., 2003). Looping supply chains are mentioned as a viable answer to total product management from "cradle to grave". A distinction is made between closed and open loop supply chains: closed loops presume that the reverse flow undertakes the same chain of the forward flow, just in the opposite direction; open loops correspond to reverse flows undertaking other paths. Our position is that the open loop configuration does not delineate integration.

Figure 3 presents some elements that would support the integration between the forward and reverse chain: improving the competing ability of the total chain, the possibility to achieve synergies (for example, economies of scale and economies of scope), better performances of the recovery process by utilising the product knowledge embedded in the forward chain, i.e., the actors of the forward chain know how the product has been manufactured (components, materials, structure).
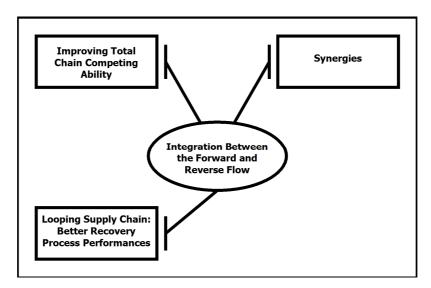
Figure 3 – Arguments supporting the integration between the forward and the reverse flow.

However, even though integration seams preferable, is it common to encounter forward chains that also embrace the reverse flow? And in the case the two chains do not converge towards integration, what are the advocated reasons?

In order to assess the level of integration, it is necessary to establish evaluation criteria. We consider the level of integration affected by the level of involvement of the original manufacturer in the reverse chain and we can assume that:

- Proposition 3. The higher is the level of involvement of the original manufacturer in the reserve chain, the higher is the probability that the forward and the reverse chain converge towards integration.

The level of integration can also be evaluated in terms of performed in-house versus outsourced reverse activities:

- Proposition 4. If the manufacturer is directly involved in the reverse chain, the probability that reverse activities are not outsourced is higher.

1.2.3 The Third Research Question: Profitability Versus Costs

Finally, the interest was also determined by that part of the literature that mainly addresses reverse logistics as pure cost for companies instead of a business opportunity. In other words, reverse logistics was viewed and is still in several cases viewed as the last element of the total product offering, the ultimate service provided to the customer to dispose the consumed product or the necessary response to environmental legislations. And the number and the scope of environmental legislations which impose companies to take back their products after use are increasing worldwide (Europe, China, United States, and Australia).

Even thought works as De Brito and Dekker, 2003, and De Koster et al., 2002, mention economic benefits as one of the drivers which moves companies to implement and run reverse logistics initiatives, companies still have a quite hard time in recognising the opportunities offered by the recovering processes.

Previous literature contributes in identifying the factors (product characteristics, presence or absence of markets for recovered products, characteristics of returns flow and customer behaviour) that may impact on the profitability of the recovery flow (Herold, 2007). However, how and to which extent these factors have an influence on profitability is quite uncertain. Besides, very few contributions present grounded cases of profitable reverse chains (Mollenkopf and Closs, 2005; Biddle, 1993; Johnson, 1998).

1.3 The Research Queries

In order to investigate which factors should be considered when designing and configuring the reverse chain (research question 1) we have considered the following set of questions:

- Is it possible to formulate guidelines, frameworks, operating models that can support firms in the process of adopting reverse logistics systems, regardless of the industry in which they operate and the product they supply? Is it possible to suggest the right reverse supply chain according to the dismissed product? How to determine which recovery option better matches the disposed product?

In order to investigate if the integration of reverse and forward flow is achievable and in which conditions (research question 2), the following set of questions have been considered:

- The idea that producers manage their products from "cradle to grave" is often mentioned in literature to synthesise the concept of closed loop supply chains. Is that realistic? Is it common to encounter such supply chain arrangements? In which conditions the two flows really integrate and manifest a clear existence of synergies?

In order to investigate if and when "reverse" represents a business opportunity (research question 3), the following set of questions have been considered:

- What are the key factors that make product recovery an opportunity for profit generation?

- How to measure reverse chain performances? What metrics to apply when considering both economical and environmental aspects?

1.4 Linking the three research questions

The three research questions are considered interrelated (Figure 4).
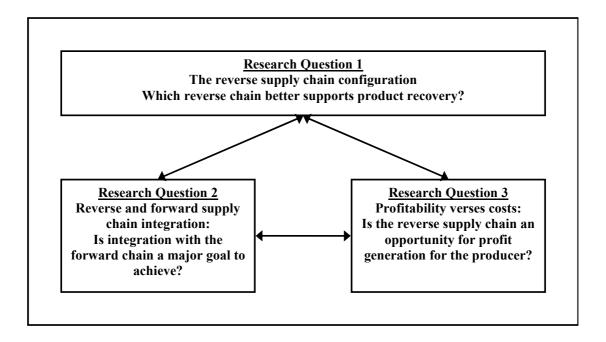
Figure 4 – The links between the three research questions.

Research questions 1 and 2 can be linked considering the relation between the reserve supply chain configuration and the level of integration between the forward and reverse chain.

In §1.2.1, we have assumed that in configuring the reverse supply chain, it is primarily relevant to identify which recovery option better supports the process of recovering product residual value. And therefore, ultimately, in order to determine the right reverse supply chain configuration, it is necessary to evaluate the product residual value. How is this related to the level of integration of the forward and reverse chain? We can suppose that:

- Proposition 5. The higher the product residual value, the higher the level of integration.

- Proposition 6. It can be assumed that recovery options such remanufacturing and refurbishment (recovery options for high product residual value) can re-utilize to some extent the production facilities, calling for synergies and economies of scale.

Research questions 1 and 3 are linked considering the relation between the reserve supply chain configuration and the profitability of the reverse flow. We argue that:

- Proposition 7. The profitability of the reverse flow is influenced by the reserve supply chain structure. When the "right" reverse supply chain structure is implemented, the possibility to extract most of the total product residual value is higher and therefore profitability increases.

Research questions 2 and 3 have been linked considering the relation between the level of integration between the reverse and the forward flow, and the profitability of the reverse flow.

- Proposition 8. It can be assumed that profitable reverse chains call for integration.

Since the level of integration has been characterised in terms of the level of involvement of the producer in the reverse chain and the extent of performed in-house versus outsourced reverse activities, verifying if research questions 2 and 3 are linked would correspond to populate:

- Table 1 which depicts the combinations between the reverse flow profitability and the level of involvement of the producer.

- Table 2 which depicts the combinations between the reverse flow profitability and the extent to which reverse activities are or are not outsourced.

If the relation between profitability and level of involvement of the producer is confirmed, only cases 1, 2 and 6 will be verified. If the relation between profitability and the extent of outsourced reverse activities is verified, cases 7, 8, and 12 will be verified.

	High level of involvement	*Low level of involvement*	*None*
Profitable flow	Case 1. The chain is profitable and the producer is directly involved.	Case 2. The chain is profitable and the producer is partially or low involved.	Case 3. No involvement
Non profitable flow	Case 4. The chain is not profitable and the producer is directly involved.	Case 5. The chain is not profitable and the producer is partially or low involved.	Case 6. No involvement

Table 1 – The relation between reverse the flow profitability and the level on involvement of the producer.

	In-house performed reverse activities	*Partially outsourced reverse activities*	*Totally outsourced reverse activities*
Profitable chain	Case 7. The chain is profitable and it is totally run by the producer.	Case 8. The chain is profitable. Part of the activities are performed in-house, part are outsourced.	Case 9. The chain is profitable and it is totally outsourced.
No profitable chain	Case 10. The chain is not profitable and it is performed in-house.	Case 11. The chain is not profitable. Part of the activities are performed in-house, part are outsourced.	Case 12. The chain is not profitable and it is totally outsourced.

Table 2 – The relation between the reverse flow profitability and in-house versus outsourced reverse activities.

1.5 The Research Conceptual Framework

Miles and Huberman, 1994 state that "conceptual frameworks are simply the current version of the researcher's map of the territory being investigated". The research conceptual framework indicates (Table 3 presents the three elements of the research conceptual framework of this project):

- Who and what is or is not studied;
- What kind of actors are studied and what aspects of their activity;
- What kind of relations.

What and who is studied	
The reverse chain	
What kind of actors are studied and what aspects of their activity	
Companies	All the activities related to any initiative to implement and run take back programs for end-of-life, end-of-use products
Public agencies	Their role as enforcing and regulating bodies
Logistics providers	Their role as providers of reverse logistics services
What kind of relations	
The relations, processes enacted to perform the reverse flow	

Table 3 – The research framework elements.

Figure 5 depicts the research arena. The reverse chain structure is determined by drivers, recovery options, characteristics of the returned products, and involved actors and

phases. The design of the reverse chain is followed by implementation and management with different possible outcomes.
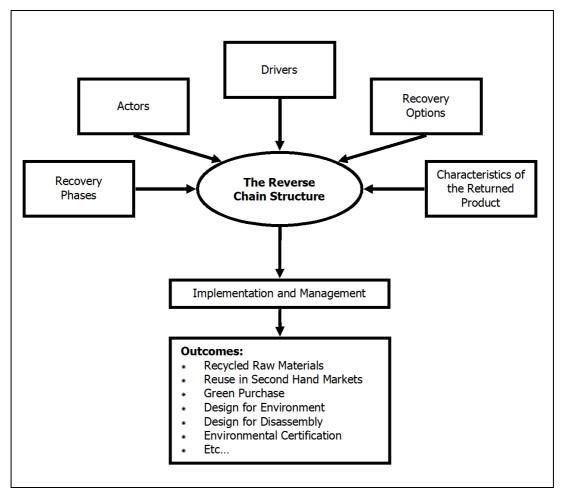
Figure 5 – The research arena.

1.6 Project Structure

The project is articulated in 10 chapters:

- Chapter 1 introduces the research field and research questions;

- Chapter 2 reviews the major contributions in the supply chain management research field;

- Chapter 3 describes the reverse supply chain, its distinctive characteristics and its main elements;

- Chapter 4 presents the research design and methodology;

- Chapters 5 and 6 present in details the two case studies of this project (the legislation driven and the value driven reverse chain);

- Chapters 7 provides the analysis of the cases;

- Chapter 8 deals with the cross case analysis;
- Chapter 9 adds on the analysis by applying two theoretical frameworks to interpret to results;
- Chapter 10 closes the thesis by summarising the results of the analysis, providing recommendations to the main actors of the reverse flow, limitations of the project and indications for further research.

The logical structure of the thesis is presented in Figure 6. The research questions (Chapter 1) derive from empirical field observations (link 2a in the Figure – Chapters 5 and 6) and the ultimate presumptions of the research field (link 1). Presumptions result from the review of the literature (Chapters 2 and 3) while an explorative round of interviews was conducted in order to elaborate basic considerations of the empirical field under investigation. Qualitative research has a number of possible techniques which can be applied in order to gather empirical data, organise the data acquired and conduct the analysis. The nature of the posed research question leads to the choice of the appropriate research technique (link 3 – Chapter 4).

Once the research technique is defined, the methodology is elaborated upon (link 4 – Chapter 4). The methodological framework has to provide the unit of analysis (the research ontological element) and the protocol used to collect, analyse, and validate the data. Chapter 4 on methodology presents in detail the methodological approach and research design applied in this thesis. The data collection process presumes to return to the empirical field with a clear understanding of which data to collect, sources, timing and scope (link 2b). The review of existing validated theories pertinent to the research questions is necessary in order to support the analysis (link 5 – Chapter 9).

The analysis of the empirical data (Chapter 7) is conducted by using the methodology in combination with the theories (link 6). The analysis leads to new knowledge creations (Chapter 8, 9 and 10). The methodology provides the data analysis structure, while theories provide meaningful insights and a logical interpretation of the findings which ultimately leads to new knowledge creation (link 7). Links, timing, the research design, as well as the process of formulating the propositions presented in §1.4 are extensively discussed in Chapter 4.
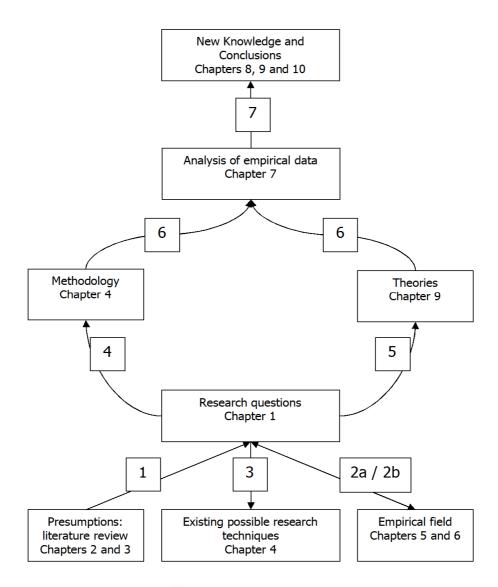
Figure 6 – The logical structure of the thesis.

1.7 Project Scope

The scope of this project is limited in many ways: industry, type of returns, companies' typology. The thesis is limited to the electrical and electronic industry, however the product range is quite broad (blenders, grinders, sawing and washing machines, medical devices and equipment, ICT equipment, communication devices, etc…).

1.7.1 Industry

Focusing on an industry helps to control extraneous variations and to define the limits for generalisation (Eisenhardt, 1989). The reasoning for focusing on electronics is that the industry is going through significant changes in recovery management. Environmental legislations force producers to consider appropriate recovery strategies

given that electrical and electronic products contain significant amounts of hazardous substances. The industry is also characterised by major and continuous changes in technologies, shortening of the product life cycles and high disposal rates. Recovery chains for electrical and electronic disposed waste are largely present in Europe due to a European Directive which has been enacted nearly in all the EU Member States. This implies data availability and the possibility to compare different implementation experiences. Due to the generally high product residual value, the electronic sector is also pertinent for investigating economic driven reverse logistics programs that are at the centre of the investigation for the profitably related issue.

1.7.2 Types of Returns

Furthermore, the thesis focuses on two types of returns: end-of-life (EoL) and end-of-use products (EoU), in both cases products that are returned by end users. This excludes returns generated within the supply chain, i.e., manufacturing returns, product recalls, by-products and packaging. The end user can convey the product to waste collection, directly back to the original supply chain (commercial returns) or directly into an alternative supply chain. End users can be both private consumers as well as companies. Since the disposing behaviour of private consumers and companies largely differ (for instance in terms of quantities and status of the returned products), disposing systems offer different services to different users.

1.7.3 Companies' Typology

The companies involved in the study are manufacturing companies, logistics service providers and recycling companies. Due to the complexity of the legislation driven chains, other actors come into place performing as providers of different types of services or as regulatory authorities.

Companies have not been selected following geographical criteria but according to the typology of the returns performed process; we aimed for at least one legislation driven reverse chain and one value driven reserve chain. Denmark offered a notable opportunity to investigate the legislation driven recovery network since the implementation process of the European Directive for the Waste of Electrical and Electronic Equipment (WEEE) was initiated in April 2005 and in February 2007, the first results of the recovery process were delivered to the Minister of Environment. The ongoing implementation process of the WEEE Directive in Italy has been used for benchmarking the planning phase.

It has not been equally easy to come across an economic driven recovery chain. The opportunity was offered by a major producer of ICT equipment, which has been

conducting in house refurbishment for a number of years, that still partly has internal recovery activities, but the major part is at present outsourced to a service logistics provider. The same logistics provider offers general reverse logistics and remanufacturing services in one country (Italy), and customer dedicated reverse logistics services in another one (Germany).

Therefore, the circumstances offered an incredible opportunity to make evaluations of in-house versus outsourced reverse chain related activities, the level of integration between the forward and reverse flow and the level of involvement of the original equipment manufacturer (OEM).

Although the initial scope was quite broad, we managed to:

- examine when reverse and forward processes are kept completely separate and when they are integrated to some extent;

- provide reasons to explain why integration and synergies are difficult to achieve and sometimes not even desirable;

- explain when reverse can become a business opportunity and partly address the problem of performance measurement systems for reverse supply chains (Chapter 10, §10.5).

As a concluding remark, we clearly mention upfront that an entire research stream devoted to quantitative modelling uses operational research techniques to model integrated and separate reverse flows, and specific aspects of the reverse flow such as facility locations planning, inventory management, routing, disassembly sequence, etc...

However, even thought the literature review on Chapter 3 mentions these contributions, this is not the approach taken in this project. It is not our intention to contribute in any way to the never ending discussion of quantitative versus qualitative research for the main reason that we believe that complementary is a good standpoint in many cases. Of course, we acknowledge that for some research, qualitative research is not science, and Chapter 3 on methodology hopefully provides enough indications on the validity and reliability that qualitative research can provide.

Furthermore, along the research journey, we never experienced the situation that the studied companies could frame their decisions by having clear upfront assumptions and complete knowledge of processes, actors and interfaces.

We also recognise that there are research streams that quarrel that bounded knowledge and rationality can also be modelled by introducing the concept of risk and probability of events. Anyway, we believe that qualitative research can provide exactly the type of knowledge that helps reducing the impact of uncertainty. Furthermore, any organisational process has some aspects which cannot be embedded in quantitative formulations. We do not neglect the importance of optimisation and in that sense, we

contributed to identify and promote the optimisation of a specific aspect of the studied legislation driven reverse chain.

1.8 Conclusions

This chapter has presented and articulated the three research questions: exploring the possibility providing a framework which supports decision making in reverse supply chain configuration, investigating the integration between reverse and forward flows, and finally examining when reverse supply chain management is an opportunity for profit generation.

The three research questions have been linked by formulating propositions that are going to be at the centre of the analysis (Chapter 8). The project structure and project scope have been outlined.

The following chapters (Chapter 2 and 3) provide a literature review on forward and reverse supply chain management and what has been achieved in terms of management components and paradigms.

Chapter 2. The Forward Supply Chain

"A study of the history of opinion is a necessary preliminary to the emancipation of the mind"
John Maynard Keynes

2.1 Introduction

In the previous chapter we stated the research problem and questions. Chapter 2 provides a literature review of the supply chain management discipline.

The supply chain management research field has undergone a remarkable evolution during the last twenty years with the contribution of difference disciplines. Concepts, frameworks, and changes in scope cannot be ignored when considering the reserve supply chain since the reverse supply chain can be seen as an extension of the forward supply chain and it would not exist if the forward one did not supply products to the market.

Furthermore, the ongoing discussion on terminology for defining supply chain management versus logistics management also affects the "reverse" world. Therefore, even thought this project deals with reverse supply chain management, this chapter provides a summary of the main stages that supply chain management undertook along its evolution, as well as a status of the debate on terminology.

2.2 The Research Context: Short Review of the Evolution of the Supply Chain Management Discipline

Since already reverse logistics and reverse supply chain are two different terms and are strictly connected with logistics and supply chain, it becomes decisively relevant to

provide a short status of the ongoing discussion on terminology within the field of supply chain management (SCM). The debate is not just purely theoretical since from the SCM definition derives which company's business processes should be included in the management model, how the supply chain (SC) is viewed, the actors involved and how they should interrelate (just to mention some of the critical elements of continuous argumentation within the field of SCM). It is also relevant to give a short excursion of the historical evolution of the field in order to understand why the terminology is still under debate, which role was played by consultants and academia to give foundations to the field, and why there is not a unique view of what a supply chain is. Many of these questions found their reasoning from the interdisciplinary nature of the supply chain management concept. Finally, we will take our position within the debate, and indicate which concept of supply chain and supply chain management is implied in this project.

The review is limited to one representing paper for each of the main evolution phases of SCM. Any reader acquainted with the supply chain management field will find the content of the chapter not exhaustive.

2.2.1 What is Supply Chain Management?

The term supply chain management was firstly introduced by consultants in the early 1980s. In the 1990s, scholars endeavoured to give structure to the growing discipline and the discussion set out from the concept of logistics management. Since then, it has received increasing attention from both practitioners and academia and its conceptualisation has changed quite noticeably over time with much broadening of its scope.

The changes in scope can be related to the changes of what is considered crucial to be managed by a company. During the late 1970s, the idea of integrating functional areas within a firm became popular in USA. The driver was the recognition that sub-optimisation occurs when each function attempts to optimise its own results rather than to establish common goals and optimise the firms total results (Ellram and Cooper, 1990). This shift from intrafunctional to interfunctional optimisation was taken further by promoting the integration of similar functional areas with the immediate suppliers and customers beyond firm's boundaries. Finally a chain/network perspective was taken by considering several tiers of suppliers and customers.

In this process of expanding the scope (both horizontally and in the intensity of the relationship), contributions to the formulation of the SCM concept came from channel and marketing management theory, and from the industrial organisation and manufacturing literature. The marketing theory posed attention to the management of the distribution channel therefore it contributed to move the interest towards the "outbound" part of the total supply chain (wholesalers, retailers, customers, final users).

The industrial organisation and manufacturing management theories opened up instead to the idea that production and all related production activities (procurement, work-in-process inventory management, just-in-time and stocks policies, total quality management, etc...) could achieve relevant improvements by collaborating with suppliers, i.e., the "inbound" part of the chain (Figure 7). Additionally, the attention slowly moved from physical materials management to supply chain management, i.e., from managing a physical flow of materials (inventory management) to managing relationships and business processes.
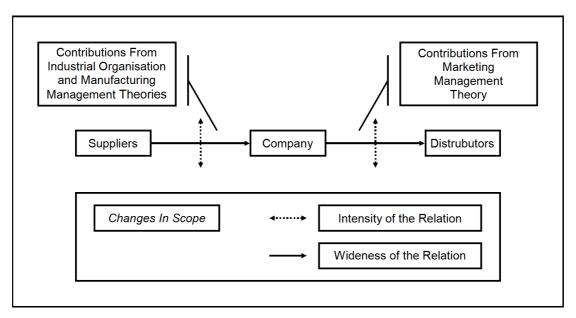
Figure 7 – SCM changes in scope and contributions from other disciplines.

2.2.2 Evolution Steps

Back in 1989, Staude indicated that while production is responsible for the creation of form utilities (conversion of raw materials into finished goods), and marketing for possession utility, physical distribution is responsible for time and place utilities, and constitutes the link between production and marketing. The link with production was identified in the common concern for inventory control, vehicle routing, and plant location (all elements traditionally analysed with a quantitative approach). The link with marketing, less easily identifiable, was found on three aspects: customer orientation, profit and integration. Physical distribution contributes to meet customer needs and create a competitive advantage by minimising stockouts, shortening lead time, and improving relationships with customers. It has a profit orientation in the sense that virtually all customers require zero lead time but this is incompatible with costs; finally it shares integration with marketing in the sense that also physical distribution would benefit from inter and intra departmental integration which are particularly stressed in

marketing. The path for relating inventory management and physical distribution to other functional areas was then traced.

In the same year, 1989, Stevens posed attention to integrating the supply chain. After the identification of which strategic, tactical and operational goals a supply chain should achieve, the author indicates the path to integration. From the first to the last level of integration, what is essentially changing is the scope of integration: from independent company's departments, through functional integration for the inward flow, functional integration towards the outward flow, and finally external integration. The first three stages all deal with intra-company integration, only the last one deals with external integration, embracing customers and suppliers. The author presumes a change of focus from production orientation to customer orientation, and from adversarial attitude to mutual cooperation. Very little is said on how to manage relationships and which elements to leverage.

In 1990, Ellram and Cooper considered a specific dyadic relation within SCM, the one between the shipper and service providers (warehouse and transportation providers). The paper indicates that collaborative partnerships between shippers and service providers should focus on removing excessive inventory. Excessive inventory derives from uncertainty in product quality, delivery time, and demand variations. Focusing "in the control and management of inventory throughout the entire supply chain" with attention "on holding inventory in the location and quantity that is optimal for the entire supply chain", is crucial to the success of the total supply chain. How to assure this success? Accurate information regarding quantity, quality and timing of inventory needs to be shared by all key players. Since channel members have been used to arm's length adversarial relations, and coercive power does not lead to trust, the recognition of mutual dependency can move to collaboration. Therefore, the authors indicate partnership as a means for sharing risks and rewards and for achieving proper inventory control. Despite the fact the paper considers a specific dyadic relation, the novelty is represented exactly by the word partnership: SCM is firstly viewed as management of relationships. Not much is said on how these relationships should be managed in order to provide benefits, and aspects as relationships largely varying in forms and changing over time are not addressed.

In 1991, Ellram described SCM as an innovative organisational form of competition to respond to the changing competitive environment. By deriving from the marketing channel literature and from the industrial organisation literature, she further explored which advantages and disadvantages SCM shares with the two organisational forms derived from the industrial organisation: vertical integration and obligational contracts. The paper represents the first attempt to use Williamson transaction costs economics (TCE) theory to investigate SCM. This research stream will be further developed since

TCE theory will become one of the most accepted theories to investigate SCM relationships.

The first attempt to draft a framework for SCM is represented by the work of Cooper and Ellram, 1993. SCM is viewed as an intermediate form between vertical integration and independent firms. The authors provide:

- the reasons for forming supply chains: to reduce inventory investments, increase customer service and built a competitive advantage;

- the characteristics of SCM: inventory management approach, total costs approach, time horizon, amount of information sharing, amount of coordination of multiple channels levels, joint planning, compatible corporate philosophies, breath of suppliers base, channel leadership, amount of risks and benefits sharing, speed of the physical and information flow. Each characteristic is then viewed in a traditional context approach and in a SCM approach (Table 4);

- the steps needed to establish a SC: what should be considered in the planning and in the operational stages? Prerequisites to any SC structure are similar corporate philosophies and the presence of a channel leader;

- finally, purchasing and logistics are indicated as the principal functional areas which can contribute to establishing and managing the SC since they can provide leadership and negotiation expertises, and experience in working with third parties.

Element	Traditional approach	Supply chain
Inventory management approach	Independent efforts	Joint reduction in channel inventories
Total costs approach	Minimise form costs	Channel wide cost efficiencies
Time horizon	Short term	Long term
Amount of information sharing	Limited to needs of current transaction	As required for planning and monitoring processes
Amount of coordination of multiple levels in the channel	Single contact for transaction between channel pairs	Multiple contacts between levels in forms and levels of channel
Joint planning	Transaction based	On going
Compatible corporate philosophies	Not relevant	Compatible at least for key relationships
Breath of supplier base	Large to increase competition and spread risk	Small to increase coordination
Channel leadership	Not need	Needed for coordination focus
Amount of sharing risks and rewards	Each on its own	Risks and rewards shared over long term
Speed of operation, information and inventory flows	Warehouse orientation (storage, safety stocks), interrupted by barriers to flows; localised to channel pairs	Distribution center orientation (inventory velocity) interconnecting flows; JIT, quick response across the channel

Table 4 – Traditional and supply chain management approaches compared (source: Cooper and Ellram, 1993).

Although the focus is still on inventory management control, the paper leads to the next step, the introduction of the business process concept which becomes explicit with Hewitt, 1994.

Hewitt uses the definition of business process given by Davenport and Short in 1990: "a set of logically related tasks performed to achieve a defined business outcome". The concept is then extended by including the definitions of process efficiency and process effectiveness (process efficiency: reciprocal of energy loss during transformation and process effectiveness: frequency of conforming outputs according to output specifications). In the SCM context, process efficiency is the reciprocal of total supply costs, while process effectiveness reflects to which extent the process is able to provide the delivery of the right product at the right place and at the right time. Given these premises, Hewitt applies the practise of Business Process Redesign (which aims at improving efficiency and effectiveness) to analyse several companies' initiatives of inter-company process redesign. It is relevant to note that the concept of business process

and business process management will become a key concept in one of the most adopted SCM definitions (Lambert and Cooper, 2000).

The year 1997 brings three key contributions. Cooper et al., 1997 in "Meshing multiple alliances" largely present and discuss the concept of relationship. The authors define what SCM is, why companies should engage in SCM, and how the chain is created and evolves. SCM is defined as an "integrative philosophy to manage the total flow of a channel from earliest supplier to the ultimate customer including the disposal process". Since SCM requires greater efforts of coordination compared to traditional management approaches, why do companies engage in SCM? The authors identify various potential benefits: economic (realise economies of scale, reduce capacity utilization risks), managerial (concentrate expertise on fewer customers and manage fewer relationships) and strategic (plan and invest for longer horizon). The path to SCM integration spans from the dyadic relation (the focus is only on the immediate contacts, i.e., the immediate customer and the immediate supplier) to vertical integration. Once SCM is contextualised, the authors move on defining relationships, how to develop relationships and why to form relationships. Relationships can span from pure arm's length to tied partnerships. Of course there is a greater degree of involvement when the relationship is becoming more tightening and the need for coordination, management time and financial commitment increases; therefore, not all relationships should be managed as partnerships.

In the same year, Betchel and Jayaram, 1997 present the first work oriented at analysing different schools of thought within SCM. The functional chain awareness school acknowledges the existence of a chain of functional areas. This school considers the total chain but it limits the analysis to the flow of materials. The linkage/logistics school presents the actual linkages among functional areas and how the linkages can be used to achieve competitive advantage. The information school stresses the importance of information exchange between the channel members, in both directions, from supplier to customer and customer to supplier. The integration/process school focuses on integrating supply chain areas by using processes. They further classify the literature into content literature and process literature. The content literature assumes that functional areas are responsible for integration, while the process literature indicates the enabling factors for integration (for instance information technology). The novelty of this paper is also an element, largely neglected before, that is the importance of using a measurement system: without measurement information, supply chain members do not have the motivation to work with others.

The last work of the year 1997, Cooper et al., 1997 can be considered with together with three other major publications: Lambert et al., 1998; Lambert and Cooper, 2000 and Lambert, 2004. These four works contain overlapping sections but what is most

interesting is that they give foundations to a largely accepted conceptual framework which analyses three fundamental elements of SCM: the supply chain network structure, the supply chain business processes and the supply chain management components.

The supply network structure is characterized by the length of the supply chain and the number of suppliers and customers at each level. Each company in the supply chain should have a clear knowledge and understanding of the supply network structure. It is crucial to identity the supply chain members: "the members of a supply chain include all companies with whom the focal company interacts directly or indirectly through its suppliers or customers, from the point of origin to the point of consumption" (Lambert, 2000). However, it would become extremely complex, time consuming and ineffective to manage all relationships with all members, therefore members should be distinguished into primary and supporting members. Primary members are "all autonomous companies or strategic business units who carry out value adding activities (operational and/or managerial) in the business processes designed to produce a specific output for a particular customer or market. Supporting members are "companies that simply provide resources, knowledge, utilities, or assets for the primary members of the supply chain". Of course the same company can perform supporting activities for a certain process and primary activities for another one. Therefore distinguishing is not always straight forward; nevertheless, defining primary and supporting members is important to define the point of origin and the point of consumption of the supply chain (beginning and end, i.e., the length). The point of origin occurs when no previous primary suppliers exist; all suppliers to the point of origin are only supporting members. The point of consumption occurs when no further value is added.

Furthermore, three structural dimensions are essential: the horizontal structure, the vertical structure, and the horizontal position of the focal company within the end points of the supply chain. The horizontal structure refers to the number of tiers across the supply chain. The vertical structure refers to the number of supplier/customers within each tier, and the focal company's horizontal position refers to the proximity to the initial source of supply or the ultimate customer, or somewhere in between.

The second element of the framework is business processes, and managing the supply chain ultimately means managing business processes. The processes identified are eight (see Figure 8).

- Customer relationship management
- Customer service management
- Demand management
- Order fulfilment
- Manufacturing flow management
- Supplier relationship management

- Product development and commercialisation
- Returns management

Lambert, 2004 presents a long explanation of the content of each of the processes. All processes are cross functional and cross organizational. The definition of business process is the one adopted by Davenport, as in Hewitt, 1994.

As managing relationships with all supply chain members is strongly ineffective, linking all business processes throughout the entire supply chain is not appropriate, and the level of integration varies from link to link and over time. Since resources in companies are scarce and valuable, proper allocation of resources among the business processes links is crucial. The allocation should consider the type of process link: managed business process links, monitored business process links, not managed business process links and not member business process links. Managed process links are links which are important to manage and integrate. Typically, the focal point manages the links with the first tier customers and suppliers. Some managed business processes links can extend further to other tiers. Monitoring process links is not as critical for the focal company but the focal company has the interest that they are properly managed between other chain members. Not managed process links are links that are not critical neither important to be monitored. Finally non member process links signals that decisions taken in other connected supply chains can influence the supply chain under scope. For instance, the first tier supplier of the focal company is typically a supplier of other companies and in case of scarce supply, which customer would be preferred? Which business processes to link and to which extent depend from the contingent situation: for instance, if there is a channel leader, it could be possible that the business processes of the channel leader will become the linked business processes of the chain.

The last element of the framework is the management components. "The level of integration and management of a business process link is a function of the number and level of components added to the link. The components presented are nine:

- Planning and control methods
- Work flow/activity structure
- Organisation structure
- Product flow facility structure
- Communication and information flow facility structure
- Management methods
- Power and leadership structure
- Risk and reward structure
- Culture and attitude

The first five components are in nature physical and technical while the last four are managerial and behavioural.

The other well known SCM framework was developed by the Supply Chain Council, in collaboration with a consulting company, and the AMR Research in 1996. The framework is called Supply Chain Operation References (SCOR) and it initially included three business processes: plan, source and deliver, which firstly need to be implemented within the firm and eventually connected across firms (Lambert et al., 2005). In 2004, the framework was expanded to include plan, source, make, deliver and return. Each process is implemented in 4 levels: level 1 defines the number of supply chains and the metrics to be used, level 2 defines the planning and execution of the material flow, level 3 defined inputs and outputs and the flow of each transaction, level 4 the implementation details. Each process implementation should include three components: business process reengineering (to picture the current status of the process), benchmarking (to determine the target values) and best practises analysis (management practises and software solutions successfully used by other companies). Best business practises should guide the implementation.

The last considered framework has been proposed by Mentzer and his colleagues (Mentzer, 2004; Mentzer et al., 2001; Gibson et al., 2005). The framework focuses on cross functional interactions within a firm and the relationships developed with other chain members.

It is in 2004 that Chen and Pauraj screened over 400 articles and tried to give a theoretical frame to SCM by identifying key constructs. They indicated 11 constructs (environmental uncertainty, customers focus, top management support, competitive priorities, information technology, strategic purchasing, supply network structure, logistics integration, buyer-supplier relationship, supplier and buyer performances) and they tested them with a survey. They concluded suggesting further extension of constructs (not much in number but in content) and further testing for correlations.

The next session shortly summarise the results of the debate on terminology up to now.
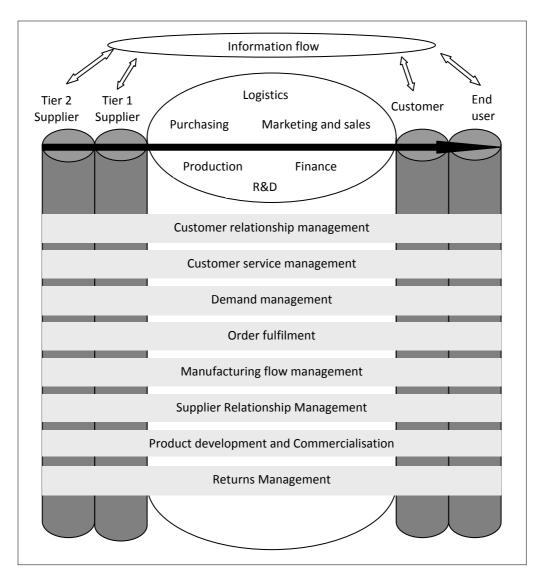
Figure 8 – Supply chain management players and processes (source: Lambert et al., 1998).

2.2.3 The Discussion on Terminology

Even though many studies have been published on supply chain and supply chain management for over the last twenty years, the distinction between logistics management and supply chain management is still an argument of discussion. And going beyond, by just screening major publications and MBA text books, it soon emerges that there is not a unique definition of the supply chain and not a single understanding of what supply chain management is.

Back in 1986, the Council of Logistics Management, a leading American professional organisation, defined logistics management as: "the process of planning, implementing, and controlling the efficient, cost effective flow and storage of raw material, in process inventory, finished goods, and related information flow from the point of origin to the point of consumption for the purpose of conforming to customer requirements". In

1998, recognizing the emerging distinction between SCM and logistics, the same CLM stated that "logistics is that part of supply chain process that plans, implements, and control the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption in order to meet customers' requirements" and in 2005 the CLM changed its name to the Council of Supply Chain Management Professionals (CSCMP).

In 1998, the Global Supply Chain Forum (GSCF) defined SCM as "the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for the customers and other stakeholders" (Lambert et al., 1998).

In 2001 Mentzer et al., reviewing major SCM definitions from 1985 to 1998, classified them into three categories: SCM as a management philosophy, SCM as an implementation philosophy and SCM as a set of management processes. SCM as a management philosophy views the supply chain as a single entity that manages the total flow of goods from suppliers to customers, synchronising intrafirm and interfirm operational and strategic capabilities to provide customer satisfaction. SCM as an implementation philosophy poses attention to the management practises that allow the implementation of the philosophy. SCM as a set of management processes provides with which processes should be at the centre of attention: managing relationships, information and materials flow. Processes should be rearranged in order to meet customer's requirements. The authors consider that confusion derives from the attempt to embrace two concepts in one term. The first, which indicates the effort for coordination from an overall system perspective, should be called supply chain orientation (SCO) while the second, i.e., the actual implementation of the coordination, should be called SCM. In other words SCO is the management philosophy while SCM is the sum of the management actions to realise that philosophy. Therefore SCO is seen as an antecedent to SCM. Other antecedents to SCM are company characteristics, like attitude to trust, commitment and interdependence, organisational compatibility, vision, key processes, leadership and top management support. SCM is the structure (three or more companies) and its processes are information sharing, risks and rewards sharing, cooperation, shared goals and focus to service the customer, process integration and long term relationships. Consequences to SCM should be lower costs, improved customer value and satisfaction, and competitive advantages (commonly seen as the result of successful SCM). The proposed definition and model of SCM embrace "the systematic and strategic coordination of the traditional business functions and the tactics across the business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the chain as a whole".

In 2005, Gibson et al. performed a survey with the members of the CSCMP. The result was that a large part perceived SCM as a combination of strategy and activity, some as a strategy that transcends individual functions, some others, a corporate function or activity, and the rest did not have a view of what SCM was. Activities included in SCM were suppliers and customer collaboration, information technology, marketing, finance, sales, and product design. The survey aimed at providing a SCM definition and it ended with two definitions:

1. Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with the channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence SCM integrates supply and demand management within and across companies.

2. Supply Chain Management encompasses the planning and management of all activities involved in sourcing, procurement, conversion, demand creation and fulfilment, and all logistics management activities. Thus, it also includes coordination and collaboration with the channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies".

The first definition became the official definition of the CSCMP.

Finally, a survey in 2007 was conducted with the intention of providing insights on the perception of logistics versus SCM (Larson et al., 2007). The interviewed panel was represented by same members of the CSCMP and the intention was to test four perspectives of logistics versus SCM: the traditional, the re-labelling, the unionist and the intersectionist. The traditionalist position views SCM as a sub function of logistics. The re-labelling simply considers a name change: what was logistics is now SCM. The unionist prospective considers logistics as a function of SCM and the intersectionist assumes that "SCM is not a subset of logistics but a broad strategy which cuts across business processes within the firm and through channels". The results of the survey point out that the unionist and the intersectionist approaches are the most popular ones. While the unionist requires an almost complete re-structuring of the company, the intersectionist appears less demanding.

The paper gives a wide array of facilitators and barriers to SCM implementation. The main facilitators are top management support, customer relationships, organisational re-structuring, integrated logistics management, electronic data interchange, internet technology, employee training, enterprise resource planning, supply chain software, and supplier involvement. While major barriers are functional silos, incompatible technology,

lack of common SCM perspective, conflicts among supply chain members, complexity of SCM, organisational structure, internal resistance, costs of the implementation, lack of electronic connectivity, unwillingness to share information.

SCM implementation is perceived as a success when customer service is improved, inventory levels decrease, cycle time is reduced, sales revenue increases and total costs decrease. The conclusions confirm that there are multiple perspectives on SCM versus logistics. Therefore, what emerges is what was said back in 2001 by Mentzer et al.: "the alternative definitions …suggest that the term "supply chain management" represents a source of confusion".

2.3 Conclusions

The broadening of the scope (interfunctional and interfims integration), and the change in nature of integrated managed activities (from managing a flow of materials to manage relationships) represent the main evolution steps of the supply chain management concept. There is no doubt that supply chain management has been initially viewed as an alternative term for logistics management. The concepts of integration, relationships management, and collaboration have been included quite early but the focus kept on gaining better materials management, i.e., removing exceeding inventory. Inputs from the marketing channel literature and the industrial management literature have contributed to provide more insights and structure to the new discipline. The first framework is dated 1993, but it still focuses on material management. In 1994, the term business process was used to indicate that supply chain management is the management of business processes within and across organisations. In 1997, several key contributions defined the how, why and what of SCM, providing quite comprehensive frameworks which greatly enlarged the scope of SCM. Almost all business processes are included in the SCM domain with few expectations, perhaps to the point that the final question would not be what SCM is, but what it is not.

Companies cannot avoid considering that they normally take part to many different supply chains, playing different roles in different supply chains, and sometimes different roles in the same chain. The managing of these many kinds and number of relationships requires the deployment of a large number and amount of resources. Therefore it is vital that a company is able to identify what are its critical relationships.

Some objections can be moved to this striving process for a common unique definition: the attempt to embrace all aspects of SCM in a single description results in quite unmanageable definitions; secondly, the result of including almost all the traditional business functions (SCM is customer relationships management, demand management, order fulfilment, manufacturing management, returns management, suppliers

relationships management, etc…) revisited in terms of business processes is that companies have a hard time in contextualising concepts and practises.

Since the purpose of this study is not testing any definition neither providing a new one, we just acknowledge the complexity of the issue. From our limited experience acquired through field investigation, we can surely assert that SCM is a multitude of relationships, processes, actors' interfaces, materials flows and information management. Customer focus is primary in order to avoid losing direction. Achieving optimal results for every single actor and for the total chain appears to be a quite challenging objective, extremely difficult to obtain and to measure. If we are called to take a position, the unionist perspective is the one that better corresponds to the case studies of this project, since logistics management (meant as the physical flow of material and its related flow of information) is only a subset of the total managed processes. Besides, our study deals with one part of the traditional supply chain since the reverse supply chain is surely part of the supply chain management discipline. While the forward flow ends with the product delivered to the end user, the reverse one starts with the product disposed by the end user. The time in-between is of course the time the product is in use.

Chapter 3. The Reserve Supply Chain

> "Nothing is created and nothing is destroyed but everything is transformed"
> Lavoisier

3.1 Introduction

This chapter reviews the main contributions that draft the reverse supply chain framework. It starts by adding on the issue of differences between the forward and reverse chains. Subsequently, the reverse chain is presented in terms of its main distinctive elements. We then provide a short review of quantitative papers that deal with the optimisations of some aspects of the reverse chain, i.e., inventory management, disassembly sequence, network design, etc… We conclude by mentioning the main definitions adopted in literature for reverse logistics and reverse supply chain management.

The literature review is organised as follows. In §3.2 the main differences between the forward and reverse supply chain are presented. §3.3 presents the main aspects of the elements of the reserve flow: drivers, recovery options, characteristics of the returned products, involved actors and phases. §3.4 presents the enabling factors and barriers for the reverse flow. §3.5 provides a review of the main contributions which consider reverse logistics using a quantitative approach. It follows a discussion on terminology and definitions of reverse logistics and reverse supply chain.

3.2 Differences Between the Forward and Reverse Supply Chain

Fleischmann et al., 2000 compare product recovery networks with traditional production-distribution networks identifying the main differences.

One major difference concerns the supply side. In traditional logistics networks, the supply can be controlled as an endogenous factor, meaning that the quality, quantity and timing of the delivered product can be tuned according to system capacity and market demand. Vice versa, in reverse networks the supply is an exogenous factor, largely unpredictable, and affected by a high level of uncertainty. Anyhow, it can be foreseen that the level of uncertainty of the supply will progressively decrease since reuse markets are only recently evolving and well monitored data are not available.

Furthermore, the nature of the supply is typically push instead of pull. It is the availability of returned products that triggers the sequence of events rather than market demand. Also the number of supply points is largely higher compared to traditional settings; this implies that high numbers of low volumes have to converge in the reverse flow.

Differences on the distribution side are not so significant, nevertheless, the level of uncertainty of the demand side, in the case of recovery networks, is usually higher since reuse markets are not so well established, and the utilisation of recycled raw materials is not so diffused.

One difference concerns with the network structure that is usually more complex in the case of recovery networks. Additional phases like inspection and separation are not present in the case of traditional logistics systems.

Lu et al., 2000 compare traditional production planning with take-back planning highlighting differences in the input variability. The composition of the incoming products can vary a lot in terms of age, model, manufacturing technology and state. High fluctuations of the demand of output materials characterise the output side. Large differences in the revenue stream depend on the payment mechanism: in recovery networks the revenue is generated when the incoming goods are received and when output components leave, depending on their quality. In some cases recovery systems have to pay for disposing low value or no recyclable output.

Fleischmann et al., 2001 derive three generic characteristics of recovery networks from a set of case studies: required coordination between the "disposer market" and the "reuse market", supply uncertainty, and disposition activities. Recovery networks are the link between the disposer and reuse markets. The disposer market is where the used products are released by the final users and the reuse market coincides with the demand of recovered products. Coordination is needed in order to match demand with the supply,

i.e., the availability of used products with the demand of recovered products, but the availability of disposed products is difficult to verify since supply uncertainty is a major characteristic of recovery networks. Lastly, disposing is a major activity of recovery networks, and the quality and status of the collected products need to be assessed as soon as possible in order to provide for the most suitable recovery option. Therefore, the destination of the recovered product can only be decided after inspection and testing. The authors further consider if including a recovery network into an existing forward network causes higher costs than simultaneous design, concluding that simultaneous design results in a more decentralised network structure while costs differences are quite negligible.

Finally, Fleischmann et al., 2004 underline differences in the main regulating network mechanism, in the product mix and in the process phases. The pull mechanism of forward networks is replaced by a push mechanism: recovery activities are mostly initiated by returned products forced into the reverse stream by legislative obligations or consumer rights. In contrast with traditional logistics systems, reverse flows present a high heterogeneous mix of products of different quality and value. The necessity to include grading and sorting arises from the need to allocate the recovered products to the most appropriate recovery option. Finally, in forward chains, the value creation mechanism traditionally implies delaying product differentiation while in recovery, the value is recaptured by revealing product conditions as earlier as possible.

Table 5 lists the main differences between the forward and reverse chain as encountered in literature. While traditional supply systems, concentrating on product demand, markets and profit, can rely on the possibility to plan according to forecasting and knowledge of the market, return flows are affected by an inherent uncertainty related to the product infrastructure (product range, material types and related quantities, presence of potential hazardous substances, manufacturing technology) which affects the recovery network infrastructure (timing, returned quantity and quality, points of collection, transportation and recovery/treatment installations capacity). While manufacturing can influence the design and production of goods, recovery and recycling companies have no influence on the characteristics of the returned products (reusability, recyclability, disassembly process).

	Forward chain	**Reverse chain**
Value stream	Value creation and delayed product differentiation	Value recovery and early product evaluation in order to reveal product status earlier
Driving mechanism	Pull mechanism: demand driven	Push mechanism: supply driven
Flow	Divergent (from one to many, typically from distributor to end users)	Convergent (from many to one, typically from end users to recovery centres)
Volumes	High distribution product volumes	High numbers of different low product volumes
Supply side	Endogenous, controlled according to production capacity and demand forecasting	Exogenous, disposal decided by the end user
Demand side	Established knowledge of customers	Limited knowledge of reuse markets and recycled raw materials market
Main phases	Procurement, production, distribution	Collection, sorting/testing, recovery, re-distribution, disposal

Table 5 – Main differences between the forward and reverse chain encountered in literature.

3.3 Main Components of the Reserve Supply Chain

In this section we present the main components of the reverse supply chain: drivers (from both an end user as well as a producer prospective), recovery options, characteristics of returned products, the involved actors, and phases. The combinations of these factors identify different types of reverse networks.

3.3.1 Drivers

Economic as well as environmental factors are commonly recognised as drivers for product recovery. Drivers are discussed in Fleischmann et al., 1997; Rogers and Tibben-Lembke, 2001; Carter and Ellram, 1998; Fleischmann, 2001, De Brito and Dekker, 2003; Toffel, 2004, Ravi et al., 2005. We review the last four contributions which summarise all the drivers identified in the literature.

In Fleischmann, 2001 three drivers are discussed: economic, marketing and legislative forces. Returned products represent cheap resources since recovery is often cheaper than producing new products and buying virgin materials. Recovery can provide marketing benefits by improving the company's market position. Growing competition can force companies to offer after sales and return service and at the same time, take-back programs improve the company's green image. Regulations are another driver which has a growing importance: the concept of extended producer responsibility has been enforced through public environmental policy in many countries. Asset protection could represent another motive for companies to take back their products after use: companies

try to prevent sensitive components from being directed towards secondary markets or competitors.

De Brito and Dekker, 2003 distinguish between drivers for the receiver and drivers for the sender. The drivers from the receiver perspective (meaning the producer) are categorized in economic (direct and indirect), legislative and corporate citizenship (Figure 9). Reverse logistics can provide direct profit by reusing raw material, by recovering value from returned products or by preventing disposal costs. Green image, market protection, improved customer-supplier relationships can instead provide indirect benefits. Legislation is another important driver due to the increasing number of directives, regulations, and take-back obligations approved in many different countries worldwide and covering a large amount of products (batteries, end-of-life vehicles, packaging, electrical and electronic appliances, etc…). Particularly in Europe, the legislation remains the main driver for most of the product recovery networks. Finally, corporate citizenship refers to the "set of values or principles" (De Brito and Dekker, 2004) that forces a company to consider social and environmental issues. This driver is particularly present in the Scandinavian countries where all major producers of consumer products release an environmental report yearly with all the initiatives taken within the company, with the supplier and the distribution channel, in order to promote environmental protection.

The drivers from the sender perspective are related to the functioning or obsolescence of the products and they can be distinguished into:

- Manufacturing returns also defined as inbound returns, when components, semi-assembled parts, and finished goods reflow into the production system. This is the case of by-products, products which fail the quality check, raw materials surplus.

- Distribution returns apply to all the returns sent out by the distribution channel. Examples are product recalls, unsold, wrong or damaged deliveries, overstocks, and functional returns of reusable distribution carriers (containers, pallets, cages, refillable bottles, reusable packaging, etc…); overstocks and obsolescence is a major return driver in sectors characterised by short product life cycle, seasonal products and quantity discount policies. In general, there is an agreement between the producer and the wholesaler/retail in order to return exceeding stocks.

- Returns initiated by the final user. Warranty returns, service returns, EoL and EoU returns are all examples of customer-initiated returns.

Figure 9 – The drivers from the receiver and the sender perspective (De Brito and Dekker, 2003).

Toffel, 2004 further distinguishes the motives for voluntary product recovery in reducing product costs, enhancing brand image, meeting changing customer expectations, protecting aftermarkets and preventing regulations. Companies have started to realise that components and materials extracted from EoL products can be refurbished and reutilised for repair or remanufacturing. Promoting an image of environmental responsibility improves the brand perception and it can be used for marketing purposes. Recovery initiatives can also be undertaken in order to meet customers' expectations: customers are becoming aware of the importance of proper product disposal, and in some cases are willing to buy recycled products. Protecting aftermarkets (markets for parts, accessories or even used products) could be relevant in cases of high value products: producers are interested to the market of new sales and they often neglect the profit stream generated by traders operating in aftermarkets.

Ravi et al., 2005 presents as drivers economic, legislation and corporate citizenship factors. The authors add environment and green issues to indicate that reverse logistics could also be a proactively conscious initiative that companies' management undertake for their own beliefs.

In general, driving forces can be internal to the supply chain or external, and determined by the surrounding environment. Summarising, external drivers can be categorised in:

- economic
- marketing
- legislative
- aftermarkets protection.

Internal drivers depend on the manufacturing and distribution processes.

3.3.2 Recovery Options

The potential of the recovery process is various and recovery options are related to the product life cycle phases: direct reuse (typically in the case of commercial returns without any major reprocessing), resale or transfer of ownership (sales on secondary markets), repair, refurbishing, remanufacturing, cannibalisation, recycling, until final disposition in the forms of incineration or landfill (Fernandez, 2004).

Most of the authors refer to Thierry et al., 1995 where different recovery options are described in detail. Five alternatives are given: repair, refurbishing, remanufacturing, cannibalization and recycling. From repair to recycling, the level of disassembly increases while the possibility to preserve the product structure decreases.

Repair aims at fixing the product in order to recover the original functionality. Refurbishing brings used products up to specified quality standards, therefore critical modules and components are inspected and if necessary fixed or replaced. Remanufacturing aims at reconfiguring the product in order to reach the same quality standards of a new product, therefore the product is completely disassembled and all modules and parts are inspected, fixed, or replaced if not approved. Cannibalization aims at recovering parts or components that can be used in repair, refurbishing and remanufacturing. Finally recycling aims at recovering value on a material level. Products' structure as well as functionality are completely lost and possible gains are generated from selling valuable recycled raw materials in the recycled raw material market.

Krikke et al., 2004 summarise recovery options and link them to recovery operations, resulting output and in which markets the output is sold (Table 6).

Options	Operations	Resulting output	Sold in:
Direct reuse	Check on damage and clean	As is, e.g., for refill	Original or similar markets
Repair	Restore product to working order, some component repaired or replaced	Original product	Original or similar markets
Refurbishing	Inspect and upgrade critical modules, some modules repaired or replaced by upgrades	Original product in upgraded version	Original or similar markets
Remanufacturing	Manufacture new products partly from old components	New product	Original or similar markets
Cannibalisation	Selective retrieval of components	Some parts and modules are reused, others scrapped	Both original and alternative markets
Scrap	Shred, sort, recycle, and final disposal	Materials and residual waste	Alternative markets

Table 6 – Outline of recovery option (adapted from Krikke et al., 2004).

There is an explicit hierarchy of product recovery options (Steven, 2004, see Figure 1, §1.2) which was originally defined in the German Commercial and Industrial Waste Avoidance and Management Act, 1996. The highest priority is given to avoidance (whenever possible), followed by reuse, remanufacturing, recycling, disposal with energy recovery and landfill. Consequently, reuse is the recovery option that should be preferred since it should imply the lowest level of waste generation and the highest level of resources and energy savings. Anyhow, this prioritisation has some downsides when considering the product life cycle in relation to the environment. For instance, from an environmental point of view, it might be preferable the option of final disposal with energy recovery than recycling whenever the balance between energy deployed in recycling and emissions for incineration is negative towards the total environmental system. This is also applicable when considering recovery and recycling legislation targets which might involve high levels of energy consumption in order to be fulfilled.

3.3.3 Types and Status of Returned Products

The types of returns have already been partly addressed when discussing the reserve logistics drivers from the sender prospective: manufacturing returns, commercial return, product recalls, warranty and service returns, EoU and EoL products returns represent different types of returns.

Types of returns are discussed in Fleischmann, 2001; De Brito and Dekker, 2003 and Krikke et al., 2004.

Fleischmann, 2001 presents EoU, commercial and warranty returns, production scrap, by-products and packaging. EoU returns are identified as the most prominent category of returns, very diversified in typology. In EoU products the author includes leased, rented products as well as EoL. Commercial returns represent a form of transferring financial risk and they can span the whole supply chain but the most common are the ones from the retailer to the manufacturer and from the customer to the retailer. They are in all cases regulated: commercial returns from customers are regulated by customers' returns rights and commercial returns from retailer are usually subjected to a contract which has the purpose of mitigating the risk of obsolescence, seasonality, short product life cycles and overstocks. Warranty returns refer to faulty products that are returned to the original sender. Failures might occur during use or transportation. Production scrap and by-products result from mechanical operations as cutting or bending, low output or quality standards. Packaging items are used to carry and contain the products; they can be easily reused after cleaning. There are economic as well as legislative motives for packaging reuse: for instance, pallets and containers are valuable packaging items which can be reused. Plastic packaging is instead normally returned due to legislation.The author also links the type of return with the cycle time, the drivers, the disposing option and actors (Table 7).

Description	Cycle time	Drivers	Disposing	Actors	Examples
1. End of use returns	Long	Economic Marketing	Remanufacturing Recycling	Original chain, alternative chain	Electronic equipment, carpet recycling, tyre retreating
		Regulations	Recycling	Original chain	WEEE Directives (European Community), White and Brown Goods Act (The Netherlands)
		Asset recovery	Remanufacturing Recycling Disposal	Original chain	Toner cartridges, impairment of computers and components
2. Commercial Returns	Short, medium	Marketing	Reuse Remanufacturing Recycling Disposal	Original chain	Retailer overstocks, fashion clothes, cosmetics, catalogue retailing
3. Warranty returns	Medium	Marketing Regulations	Repair Disposal	Original chain	Defective household appliances, routable spares
4. Production scrap and by products	Very short	Economic Regulations	Recycling Remanufacturing	Original chain, alternative chain	Pharmaceutical industry, steel works
5. Packaging	Short	Economic	Reuse	Original chain, alternative chain	Pallets, crates, bottles
		Regulations	Recycling	Original chain	European legislation

Table 7 – Characteristics of difference categories of returned products (Fleischmann, 2001).

Be Brito and Dekker, 2003 consider composition (number of components and materials), deterioration status (how much of the original functionality is left) and use-pattern (location, intensity and duration of use) in order to identify the type of returned product.

Krikke et al., 2004 identifies four types of returns: EoL, EoU, commercial returns and reusable items. EoL returns are returns taken back from the market to avoid environmental or commercial damage. EU legislation based on Extended Producer Responsibility and directives imposing material collection and recycling targets generate this type of returns. Very often the reverse chain dealing with this type of returns is an alternative chain. EoU are products or components returned after some period of operation (for instance leased or trade-in products, or returns from product replacement). Since they can retain high economic value, it is essential that they are quickly processed and remarketed. Similar to forward chains, the time based economic value of EoU returns necessitates a responsive reverse chain.Commercial returns are related to the sales process. Developments in mail order and e-commerce sales have strongly increased the return rate. Overstocks are also part of this category. These are very time sensitive returns, since in most of the cases the products can just be

remarked. Reusable items are not part of the product itself but they are used to contain/carry the actual product. Examples are reusable containers, pallets, refillable bottles, refillable toner cartridges, etc…

Even though in the literature EoU and EoL are sometimes used as synonymous, we make a distinction between EoU and EoL returns which in our view represent two very well distinguished types of returned products: EoU products, to the contrary of EoL products, might still preserve intact the functionality. EoU products are usually generated by major technological breakthroughs which cause obsolescence or simply by customers' changed preferences (for instance replacement of mobile phones, audio-video recording and reading devices, LCD - liquid crystal display - monitors replacing CRT - cathode ray tube – monitors, returned leased and trade-in products). The distinction is relevant since EoU products might flow into secondary markets which represent a form of prolongation of the life cycle that delays the moment the product becomes waste, but also generates concerns on where the product ultimately ends up to be waste, e.g. countries with no proper disposing regulations. EoL returns are instead characterised by a low economic value and the product functionality is lost.

3.3.4 Actors

Type and number of actors vary a lot according to the type of recovery network, if the disposed product flows back into the original forward chain (closed loop chain) or if it enters an alternative chain, and when an alternative chain is undertaken, if it is specialised on a particular set of recovery options or not. Generally, disassembly involves specific knowledge of the production process therefore original producers more likely are involved in the take-back process. On the contrary, recycling is usually performed by specialised dedicated companies with very generic recycling technologies.

Anyway actors can be distinguished in (De Brito and Dekker, 2004):

– actors of the original forward chain (suppliers, manufactures, wholesalers, retailers);
– actors of specialised recovery networks (recycling and refining companies, dedicated logistics providers, dedicated transporters, municipalities, governmental agencies, brokers, etc…);
– opportunist players.

The number and type of actors in dedicated recovery networks is usually larger than closed loop networks. This introduces a higher level of complexity in the coordination mechanism and in identifying the central decision maker.

3.3.5 Phases

The last reverse chain dimension deals with the steps the product undertakes when disposed. All the following contributions present in details product recovery phases: Fleischmann et al., 2001; Fleischmann, 2001b; Guide Jr. and Van Vassenhove, 2002; Krikke et al., 2004; Prahinski and Kocabasoglu, 2006; Walther et al., (forthcoming). Depending on the kind of network, the type and number of the recovery phases might change. However, the following set of activities appears to be recurrent:

– acquisition/collection
– transportation which might also follow inspection and separation, depending on the network structure (centralised versus decentralised)
– inspection/selection/separation/sorting
– reprocessing/reconditioning
– disposal.

Reconditioning, redistribution and sales are typical of recovery networks that reintroduce remanufactured/refurbished products in the original and/or in the secondary markets (Figure 10).

The different phases are defined in Prahinski and Kocabasoglu, 2006. Acquisition is the process of obtaining the product from the customer. Collection and transportation are the processes of retrieving the product from the end customer for the purpose of capturing value or proper disposal. Inspection and disposition have to determine the level of quality of returned products and the appropriate recovery option (reuse, product upgrade, materials recovery and waste management). Reconditioning operations carry out the chosen recovery strategy and are followed by distribution and sales.

In Walther et al., (forthcoming) the phases of a typical recovery network which essentially deals with waste are described. Discharged products are picked from end users delivery locations or at the producers' premises. Products are then conveyed to recycling companies where disassembly and bulk recycling is carried out. Disassembly has to guarantee the removal of hazardous and harmful substances and the extraction of valuable materials. Recycling aims at recovering various metal and plastics fractions. After recycling, the recovered materials fractions are delivered to refining companies and disposal facilities.

In general, collection accounts for a significant part of the total recovery costs since a large number of low volume flows make collection an expensive operation. The location of the testing and grading phases needs to be properly considered according to product residual value. Early testing is suggested in order to direct the returned product to the proper recovery operation; however, early testing implies a decentralised network which minimises transportation costs but increases investments on local testing facilities. It is

transportation and reprocessing that are the most costing phases of the whole recovery chain. Reprocessing, with the high investments required for specialised remanufacturing and recycling plants and equipment, strongly influences the economic viability of the entire chain (Fleischmann, 2001b).
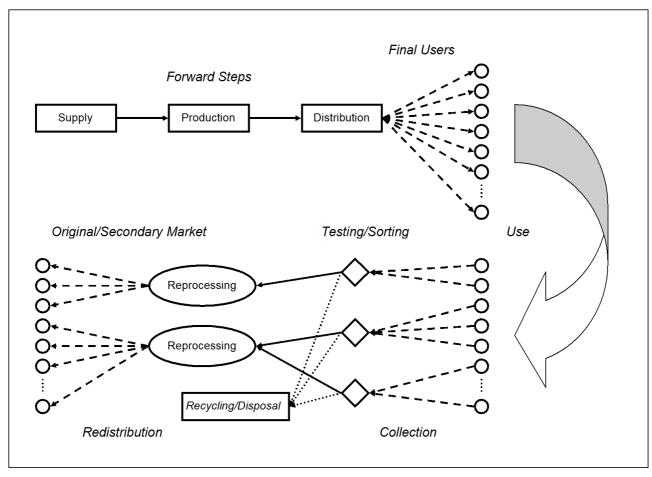
Figure 10 – Forward and reverse phases (adapted from Fleischmann et al., 2000 and Fleischmann, 2001b).

3.3.6 Recovery Networks Types

The combination of recovery options, types of returned items, drivers and design parameters determines different networks types and configurations. We hereby consider four contributions that present four different approaches in order to categorise recovery networks.

In Fleischmann et al., 2001 a certain number of case studies are analysed in order to identity distinctive characteristics of recovery networks. The authors indicate the degree of centralisation, the number of levels, the links with other networks, open versus closed

loop structure and the degree of branch cooperation as the factors which set the context for networks classification.

The centralisation refers to the number of locations which execute similar activities. The number of levels refers to the number of facilities a product visits sequentially; the number of links with other networks measures the degree of integration of the new network with previously existing ones; open versus closed loop structure defines the relation between incoming and outgoing flows (in closed loops the source corresponds to the sink while in open loops the entering point and exit points do not coincide). The degree of branch cooperation indicates if a single company is engaged in the network or companies of the same industry/sector collaborate. The authors argue that recovery network types are context dependent and are influenced by:

- physical and economical product characteristics that affect the degree of centralisation, the number of the levels and the recovery option;
- supply chain characteristics that determine relationships and behaviours of the actors and the driving forces;
- resource characteristics (referring to both human capital and recovery facilities) meaning the degree of resource flexibility (dedicated versus universal) and the level of fixed costs for specific investments.

By combining network properties with context variables they conclude by identifying three network types:

- bulk recycling networks
- assembly product remanufacturing networks
- re-usable item networks

The characteristics of each network type are summarised in Table 8.

Fleischmann, 2001b extends the classification including two context variables: the drivers for product recovery (economic versus legislation) and the ownership of recovery. The author identifies five possible combinations (Table 9).

1. Networks for mandated product take back. They are established to respond to environmental product take back legislations. Original equipment manufacturers (OEMs) are responsible for separate collection of their products. Since the product residual value is limited, recycling is the most suitable recovery option and the network aims at costs minimisation. While OEMs are held responsible for take back and recovery, the operations are outsourced to logistics providers and specialised recycling companies. These networks are usually formed by industry associations, and they do not involve sophisticated operations (only collection and separation by product category).

2. OEMs networks for value added recovery. They are closed loop supply chains managed by OEMs with the objective of recapturing value from the used products. Used products are of high value and close cooperation with customers allows easy product collection. Recovery options are quality dependent and they can be at the product, component or material level. Testing and grading are crucial and the tendency is towards centralised testing operations.

3. Dedicated remanufacturing networks. Specialised remanufacturing networks have been present for a long while. They are operated by brokers, or brokers are involved in selling the output of the remanufacturing process. Rather than adding the collection infrastructure, remanufacturing companies design an integral network which covers the supply of used products and the demand of remanufactured products. The management of the supply side is vital to assure a reasonable incoming flow. The main goal is profit maximisation rather than cost minimisation.

4. Recycling networks for material recovery. Recovery is at the material level. They are characterised by low profit margins and they require high investments for specialised recycling equipment and installations. Low profit margins and high investments call for high processing volumes and economies of scale exploitation.

5. Networks for refillable containers. Refillable containers can be used after minor cleaning and checking. Since the company relies on the proper return of refillable containers, availability assured by the logistics network is important. Availability concerns the collection strategy, the routing of the empty containers, and depot locations.

	Key elements	Characteristics
Bulk recycling networks	▪ low value products ▪ different disposer and re-use market ▪ high investment costs ▪ centralised, open loop structure ▪ limited number of levels ▪ high branch cooperation	Combining low value per volume collected with high investment costs results in the need to achieve high processing volumes. Branch cooperation is a way to assure high processing volumes. Centralised structure determines the necessity to exploit economies of scale.
Assembly product remanufacturing networks	▪ re-use of product or parts of high value ▪ recovery carried out by OEMs ▪ re-use and original use coincide ▪ high operation costs ▪ complex multi-level structure ▪ closed loop ▪ rely on existing logistics systems	Added-value recovery is the main driver and since recovery requires product manufacturing knowledge, mainly OEMs carry out the process. However if market entry barriers are low, recovery opportunities attract third parties. Decentralisation derives from the need to detect in advance product conditions.
Re-usable item networks	▪ high importance of returns timing ▪ decentralised, single level structure ▪ depending on existing logistics systems ▪ closed loop ▪ high transportation costs	Only minor reprocessing required, therefore the network is rather flat, with levels that correspond to depots. Closed loop since there is no distinction between original use and reuse. It is relevant to determine the number of items required to run the system (capacity). Transportation is the major cost and this may be a reason for decentralisation.

Table 8 – Summary of characteristics network types (adapted from Fleischmann et al., 2000).

	Economically driven			Legislation driven		
	reuse	remanufacturing	recycling	reuse	remanufacturing	recycling
OEM	5	2	4	-	-	1
Third party	5	3	4	-	-	1

Table 9 – Reverse logistics networks classification (adapted from Fleischmann, 2001b). The numbers corresponds to the network recovery type previously described. Empty combinations mean that no examples of those types of networks have been found.

De Brito et al., 2002 classify a great number of case studies from many different industries on a strategic, tactical and operational level. The strategic level corresponds with the network design, the tactical level with the managing of the relationships, and the operational level with inventory control and recovery activities. Combining a new dimension concerning the initiative (public or private) and the recovery options (re-use, remanufacturing and recycling), the authors outline four classes (Table 10 - no public reuse or remanufacturing networks have been found in their study).

	Reuse	**Remanufacturing**	**Recycling**
Public	-	-	Public reverse logistics networks driven by environmental regulation (batteries, white and brown goods, car recycling, glass recycling)
Not public	Networks for reusable items (containers, packaging, refillable bottlers)	Networks for remanufacturing (scanners, printers, copy machines, faxes)	Networks for product recovery (carpet, building debris)

Table 10 – Network types (De Brito et al., 2002).

Bostel et al., 2005 combining types of returns derived from Fleischmann et al., 1997 with recovery options described in Thierry et al., 1995, identify four types of networks:

– Directly reusable networks: returned items can be directly reused without major reprocessing (pallets, bottles, containers). They are closed loop networks since the forward flow is closely associated with the reverse one.

– Remanufacturing networks: product, parts or components are remanufactured in order to be reused (copy machines, aircraft engines). These networks are closed loop since remanufacturing is usually performed by the original manufacturer.

– Repair service networks: defective products are repaired. They are open loop systems since in this type of networks there are few links with the forward flow.

– Recycling networks: raw materials (glass, metals, plastics, paper) are recycled by specialised providers therefore they can be considered open loop.

3.4 Enabling Factors and Barriers for the Reverse Flow

We briefly address two contributions which have discussed enabling factors and barriers for reverse logistics.

Krikke et al., 2004 identify enforcing and enabling factors for the reverse supply chain. With the view of promoting the concept of managing a product from "cradle to grave", the authors derive from the analysis of two cases what are the factors to be considered for closed loop supply chains. Enforcing factors correspond with the previously discussed drivers: legislation and business motivations. Enabling factors are represented by future supply chain developments that can positively impact the reverse chain and new technologies (Figure 11).

Rogers and Tibben-Lembke, 2001 by carrying out a survey with members of the Council of Logistics Management, identify main barriers for reverse logistics. In order of importance they are:

- Importance of reverse logistics relative to other issues: reverse logistics does not receive priority within the company.
- Company policies: fearing the danger of market cannibalisation or brand damaging, the company clearly avoids implementing return policies.
- Lack of systems: this refers to the lack of information technology systems to receive incoming goods and proceed with inspection, registration, and recovery option selection.
- Competitive issues: existence of dedicated service providers which perform reverse logistics more efficiently.
- Management inattention.
- Personnel resources and financial resources: implementing new systems and processes requires investments in terms of personnel training and financial resource usage.

What looks more promising are the improvements in technologies for designing more environmental friendly products, and products which can be easier handled in the recovery processes (the design for X techniques – design for disassembly, design for remanufacturing, design for recycling, etc…). Furthermore, life cycle analysis provides a detailed examination of the environmental impact of the product along its entire life cycle, from design to disposal. Therefore, what emerges is that reverse supply chain management can surely benefit from the new techniques and technologies that can assist product design and product life cycle management. However, the vision emerging from the academic contributions that have considered the limitations of the mandatory product take back legislations, especially in Europe, is that the legislation does not provide incentives for the employment of these techniques. On the other hand, barriers naturally exist in terms of limited resources to allocate too many other different issues, lack of commitment and investments on information technologies tools.
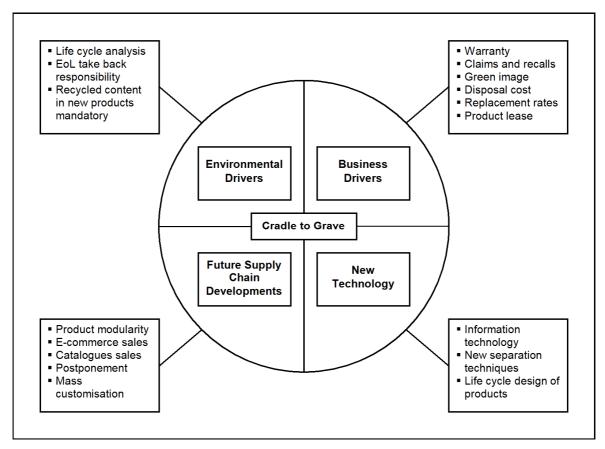
Figure 11 – Enforcing and enabling factors (Krikke et al., 2004).

3.5 Optimisation Models for the Reverse Chain

The section provides a condensed literature review of papers which have elaborated optimisation models for the reverse flow at various levels. Most of the models are based on operational research techniques.

We use the characterization indicated by Bostel et al., 2005 in order to review all major contributions for reverse logistics networks design and optimisation. Bostel et al.. 2005 indicate a hierarchical planning approach (strategic, tactical and operational). At the strategic level, a distinction is necessary between independent reverse logistics network design models and integrated models with weak or strong correlation with a pre-existing forward network. At the tactical and operational levels, we encounter optimisation models for inventory management (deterministic, static, stochastic, single period review systems, periodic and continuous review systems), or flow optimisation (transportation and production planning models).

Most of the studies at the strategic level are represented by facility location models. Queiruga et al., 2007 and Walther et al., 2005 specifically deal with facility locations planning in the case of WEEE recycling. The first study provides a method to rank

alternatives for recycling plant installations in Spain by using a discrete multi-criteria decision method combined with experts' panel survey. The second focuses on facility location planning for treatment of large household appliances. Similarly to Queiruga et al., 2006, Walther et al., 2005, pre-select municipalities appropriate to host recycling plants considering economical, social, infrastructural, legal and environmental criteria by applying a Multi-Attribute Decision Making (MADM) procedure. MADM methods are often used for location planning of manufacturing systems and they present the advantage to simultaneously consider qualitative and quantitative factors needed in the case of recycling plant locations. On a second stage, location interdependences are analysed by using a Warehouse Location Model (WLM) in order to determine an optimal recycling system.

Other contributions consider the problem of locating collection areas for urban waste. Similarly to Queriruga et al., 2007 and Walther et al., 2005, Vuk and Kozelj, 1991 apply the PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) methodology and the geometrical representation of multicriterional analysis (GAIA) to select locations for disposal of municipal waste in Slovenia. Baustista and Pereira, 2005 develop a mathematical model and an algorithm to solve the model by using the set covering problem methodology (SCP). A GRASP heuristics (constructive multi-start procedure allowing the generation of multiple solutions for a single problem) is used to solve the MAX-SAT (maximisation of the number of clauses that should be satisfied) problem and support decision making for waste collection sites locations.

Several studies concentrate on modelling at the network level, with no correlation, weak or strong correlation with the existing forward network. The most complete contribution which values the impact of recovery flows on existing forward networks is Fleischmann et al., 2001. By using a MILP (Mixed Integer Linear Programming) model, the authors evaluate if independent design causes higher costs than simultaneous design, concluding that integral design results in a more decentralised network structure while cost differences are quite negligible: therefore traditional logistics systems are proven to be robust when coming to physical product recovery network design. The testing is performed by using two specific examples: photocopier remanufacturing and paper recycling.

At the network level, two recent studies particularly deal with WEEE recovery optimisation. Walther and Spengler, 2005 use a linear activity base model in order to optimise the allocation of discharged products, disassembly activities and disassembly fractions to actors of the treatment system. The model is developed combining reverse logistics and disassembly planning models and aims at maximising the annual marginal contribution of the network as the sum of acceptance and sales revenues minus sales, transportation, sorting and disassembly costs. Walher et al., 2006 explore the negotiation coordination mechanism in product recovery networks by using contract theory in order

to represent the network as a continuous exchange of sensible and private information which requires a negotiation mechanism between the focal company and the recycling companies. Contractual agreements are necessary since the focal company has to agree with each recycling company on the masses to collect, the recycling targets and the recycling prices. In their evaluation, they consider the focal company as the most powerful actor controlling the negotiation process; therefore a hierarchy is decided in terms of contractual power. Assumptions are taken on the frequency of the negotiations (quarterly basis). By modelling the interdependencies between recycling levels, material fractions, allocation of material fractions to recovery and disposal sites, sales revenue and recycling targets with a centralised and decentralised planning model approach, they compute the optimal recycling strategy by maximising the total marginal contribution of the network. The model is an extension of the contribution of Walther and Spengler, 2005 with the interesting novelty of representing the network as a set of negotiation mechanisms between the focal company and the recycling companies. A Lagrangian relaxation of the constraints is used in order to explore the decentralization coordination.

We mention other two contributions addressing optimization at the network level: Shih, 2001 which aims at optimizing the infrastructure design of the reverse flow by minimising the total costs as the sum of the transportation, operating, fixed and final disposal costs) and Kara et al., 2007 that present a simulation model to calculate collection costs for EoL appliances in the Sidney Metropolitan area.

At the tactical and operational level, several of the existing contributions analyse the possibility of ensuring an efficient deployment of resources over certain time horizons (medium or short-term) and to optimise specific activities along the recovery chain. The main issues discussed are: inventory levels, production's planning and scheduling, vehicle routing.

Bostel et al., 2005 review major contributions dealing with operation and tactical models. It emerges substantial differences in the flow type (exogenous inbound flow) and in the supply characteristics (multiple supply sources). Therefore, operation models for reverse logistics strictly depend on the particular reverse network (timing, quality and quality of the returned product). For a recycling network, it is irrelevant to simultaneously consider forward and reverse flows, since recovered items are transformed into raw materials and the system has no relations with the original supply flow. In all the other cases (repair, directly reusable items, remanufacturing), the correlation between forward and reverse flow is stronger.

Classical EOQ (Economical Order Quantity) models for inventory optimisation are used in a deterministic and static environment where demand and returns are constant, and the lead time is fixed. Dynamic approaches instead apply the Wagner-Within model in

order to determine dynamic lot sizing and inventory status. Stochastic models for a single period are used to study e-commerce and mail sales returns. Periodic review models are applied for optimal control policy based on disposal, remanufacturing and new supply. Continuous review systems models consider stocking points (number and location), disposal options, and the influence of the return rate.

Fleischmann et al., 2002 present a single item continuous review inventory model with Poisson demand and returns. The model minimises the long-run expected average costs per time considering fixed lead times, unserved demand as backlogged, and random returns occurring unit by unit. Similarly, Fleischmann and Kuik, 2003 analyse the impact on the reverse inbound flow on inventory control in the case of a single inventory point with independent stochastic demand and returns. The solution is elaborated by considering a variant of a traditional stochastic single item inventory (traditional (s, S) order policy model) where demand can be positive or negative.

Bayındır et al., 2006 investigate the proper level of recovery under four different inventory control policies. The objective is to find the optimal recovery level and the inventory control parameter that minimise the average total costs. The considered inventory system is for a single item with two different supply sources: brand new items purchased from an external supplier and recovered used items.

Franke et al., 2006 elaborate a capacity and facility adaptation planning model for remanufacturing mobile phones. A linear optimisation model is elaborated upon for planning considering periodic adaptation of existing remanufacturing capacity responding to fast changing product process and market constrains, and a discrete-event simulation is elaborated by using an algorithm which has as input the results of the linear optimisation. Realff et al., 2004 consider a similar problem (production infrastructure design) by applying a linear programming model that searches for optimal solutions in the case of a set of alternative scenarios. The model is tested in an industrial case study for carpet recycling.

Other contributions address the problem of optimal disassembly planning.

Lambert, 2006 presents a near-optimum solution for the disassembly sequence. The product structure is assumed to be hierarchical and the disassembly process considers the bill of material to develop the corresponding divergent disassembly graph. The mathematical model is formulated as an asymmetric constrained Travelling Salesperson Problem (TSP) and it is solved with two approaches (integer programming and iterative) where the number of integer variables is reduced modifying the two-commodity network flow method.

Teunter, 2006 proposes a stochastic dynamic programming algorithm for determining the optimal disassembly strategy considering the disassembly tree, the process-

dependent quality distribution of assemblies, the quality-dependent recovery options and related profits for assemblies.

The algorithm generalised the one proposed by Krikke et al., 1998 by allowing multiple and partial disassembly processes.

Kongar and Gupta, 2006 propose a multi-criteria optimisation model of a disassembly-to-order system. In this case, the problem is not to determine the optimal disassembly sequence but to find the optimal combination of the number and type of products to take back from the disposing market in order to extract components and materials to meet a certain level of demand under physical, financial and environmental constrains. This approach is subjected to the assumption that not all disposed products are due to be taken back but only the share which is needed to serve the demand, therefore the disassembly-to-order situation does not correspond to a legislation driven network which has as primary constrain to assure that all disposed products are collected and treated.

3.6 Terminology

Since the existing literature uses different terms as reverse logistics, reverse supply, product recovery, recovery networks and the purpose of this study is not to contribute on the terminology discussion, the terms will be used hereinafter as synonymous keeping in mind that the term "supply chain", and therefore the reverse supply chain, indicates a broader scope horizon than logistics. Logistics and consequently reverse logistics is considered to deal with the material flow and the related flow of information while reverse supply chain management is meant as the all set of processes, relationships, agreements, procedures, planning, implementation and execution of all flows. In this context, reverse logistics is considered as one of the supply chain management processes and the management of the relationships, agreements, and procedures for reverse logistics is "placed" within the supply chain.

We suppose that considering the reverse flow as a separate chain (reverse supply chain) or as part of the forward supply chain (reverse logistics) is mainly related to the level of integration of the two flows which determines the possibility or impossibility of integrated management.

Definitions of reverse logistics have been presented in Pohlen and Farris, 1992; Kroon and Vrijens, 1995; Fleischmann et al., 1997; Stock, 1998; Carter and Ellram, 1998; Fleischmann, 2001a; De Brito and Dekker, 2004; and Bostel et al., 2005. The definition of product recovery management can be found in Thierry et al., 1995; closed loop supply chains in Guide et al., 2003; Geyer and Jackson, 2004; reverse supply chain in

Guide and Van Vassenhove, 2002; Prahinski and Kocabasoglu, 2006. The definitions are listed in Table 11.

The definition of reverse logistics given by Pohlen and Farris, 1992 presumes the movements of products from the user all way back to the producer. Kroon and Vrijens, 1995 underline that reverse logistics implies management skills and management activities. Fleischmann et al., 1997 add on the purpose of the backward flow to obtain reusable items. Stock, 1998 broaden the meaning and the scope of activities of reverse logistics including product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal, refurbishing, repair and remanufacturing. Carter and Ellram, 1998 pose the attention on the environmental aspect of reverse logistics.

Rogers and Tibben-Lembke, 1999 and Fleischmann, 2001a complete the definition with considerations of efficiency and cost-effectiveness.

De Brito and Dekker, 2004 as Rogers and Tibben-Lembke, 1999 consider not only finished goods flowing back but also raw materials, in-process inventory and packaging material.

The definition of product recovery management given by Thierry et al., 1995 poses the responsibility for the management of used and discharged products, components, and materials on the manufacturing company. This concept will be used lately in much legislation to state the extended responsibility of the producer, from production to disposal.

The concept of closed loop supply chains is introduced by Guide et al., 2003 and Geyer and Jackson, 2004. The term wants to embrace both the forward and reverse flow. Often the distinction is made between open and closed loop supply chains, where closed loop supply chain means that the supply chain that receives the secondary sources produces goods of the original type while in the open supply chain the goods are different (Geyer and Jackson, 2004). Closed loops also presume that the returned products flow back thought the same chain of the forward flow.

Reverse supply chain management definitions instead focus on the series of activities required for retrieving a used product from customers for the purpose of disposing or reuse; therefore the attention is uniquely on the reverse flow.

We find the definition elaborated by Fernandez, 2004 the most comprehensive one:

Reverse supply chain is….“The management of activities, processes and actors interfaces that assures the recovery of any type of items (used or not used, finished products or just components, parts or materials) which for different reasons are sent back by any member of the supply chain to any of the previous member of the same chain.. This includes decisions of in house or outsourcing recovery (the recovery steps are performed by the original equipment manufacturer or by specialized companies),

decentralized or centralized returns centres, inspection and recovery policies, recovery and disposition options. 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".

Table 11 summarises the main definitions encountered in the literature.

Definitions of reverse logistics	
Pohlen and Farris, 1992	The movement of goods from a consumer towards a producer in a channel of distribution.
Kroon and Vrijens, 1995	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.
Fleischmann et al.,1997	Reverse logistics encompasses the logistics activities all the way from used products no longer required by the user to products again usable in a market.
Stock, 1998	From a business logistics perspective, the term refers to the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal, and refurbishing, repair and remanufacturing; from an engineering logistics perspective, it is referred to as reverse logistics management (RLM) and is a systematic business model that applies best logistics engineering and management methodologies across the enterprise in order to profitably close the loop of the supply chain.
Carter and Ellram, 1998	Reverse logistics is a process whereby companies can become more environmentally efficient through recycling, reusing, and reducing the amount of materials used.
Rogers and Tibben-Lembke 1999	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 or recapturing value or proper disposal.
Fleischmann 2001a	Reverse logistics is 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.
De Brito and Dekker, 2004	The process of planning, implementing and controlling backwards flows of raw materials, in-process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal.
Definition of product recovery management	
Thierry et al., 1995	Product recovery management encompasses the management of all used and discharged products, components, and materials that fall under the responsibility of a manufacturing company.

Definitions of closed loops supply chains	
Guide et al., 2003	Closed loop supply chains include the traditional forward supply chain activities and the traditional activities of the reserve chain.
Geyer and Jackson, 2004	Supply loops are product end-of-life management strategies that fulfill two criteria. ... They divert end-of-life products from landfill and incineration… secondary resources that result from the reprocessing of these end-of-life products replace primary resources in forward supply chains.
Definition of reverse supply chain	
Guide and Van Vassenhove, 2002	It is a series of activities required to retrieve a used product from a customer and either dispose it or reuse it.
Prahinski and Kocabasoglu, 2006	Reverse supply management is defined as the effective and efficient management of the series of activities required to retrieve a product from a customer and either dispose it or recover value.

Table 11 – Definitions of reverse logistics, product recovery management, closed loop supply chains and reverse supply chain.

3.7 Conclusions

Whenever the reverse supply chain is seen as an extension of the forward supply chain or as a separate chain, it is not possible to investigate the reverse flow without a grounded knowledge of the forward one. Therefore Chapter 2 has provided a review of the fundamental evolutions steps of the supply chain management field and Chapter 3 has proceeded with an evaluation of the main contributions adding to the reverse supply chain framework. The main distinctive elements of reverse chain have been presented: drivers, recovery options, types of returns, actors, phases, and recovery networks types. Reverse logistics has been investigated also with a quantitative perspective therefore the literature review is completed with an analysis of a series of quantitative papers that deal with optimisation problems for specific aspects of the reverse chain, Finally, the main definitions adopted in literature for reverse logistics, reverse supply chain and recovery management have been considered.

Summing up, even thought there is not unanimity of which direction the product undertakes once it abandons the forward supply chain (the same path of the forward flow, just in the opposite direction or alternative paths in relation to the recovery option), "reverse" always implies a backward direction. In a broad sense, the management of materials (products, components and packaging) is involved. Managing the reverse flow requires competences, capabilities and specific knowledge of problems that for many aspects differ from the forward flow. While the forward flow aims at delivering the products/services to the market, the reverse flow aims at taking products back after consumption, and the exchange of information between the actors involved in the reverse flow is crucial in order to direct the recovered product to the right recovery channel.

Chapter 4. The Research Design and Methodology

"An expert is a man who has made all the mistakes which can be made in a very narrow field"
Niels Bohr

4.1 Introduction

The chapter presents the research design and the research methodology applied in this project. The methodological positioning, the research approach, the research technique, the data collection process and the analysis process are examined. While shortly elaborating on main elements of the chosen research technique (case study research), we provide motivations to support our decisions concerning the methodological approach and how the different logical steps have been undertaken in a quite substantial iterative mode.

Two case studies have been chosen in order to comply with the sampling logic suggested by Yin, 2003. The sampling logic suggests that the cases do not have to represent a population, rather highlight commonalities and differences. One case is represented by a legislation driven recovery chain, the second chain is instead value driven.

The chapter continues presenting the research process, the data collection process and how the analysis has been conducted. The tests for reliability and validity (Yin, 2003) present the measures that have been taken in order to guarantee the quality of the research. Before presenting the methodological approach, we shortly elaborate on the theoretical paradigm which represents the foundations and the departing point for any researcher.

4.2 The Theoretical Paradigm

Within social science, the choice of the appropriate research methodology depends on the type of research question, the control the investigator has over the actual behavioural events and the focus on contemporary as opposed to historical phenomena (Yin, 2003).

However, ultimately the choice of the research methodology also depends on the paradigm of any individual researcher (Arlbjørn and Halldorsson, 2002). The paradigm consists of all the meta-theoretical assumptions a researcher has regarding the ontology and epistemology of his/her study. Ontology refers to the conception of reality, what reality is, while epistemology refers to the nature of knowledge, what knowledge is and how it is generated. The ontology provides for the reality (entity) under investigation while epistemology for how reality can be known.

Social scientists have adopted six main ontological approaches (others exist):

- Realism asserts the idea that facts are out there just waiting to be discovered.
- Empiricism emphasizes the role of experience, especially sensory perception, in the formation of ideas.
- Positivism values authentic knowledge only the scientific knowledge which comes from positive affirmation of theories through strict scientific methods.
- The post positivism paradigm attempts to resolve the main criticisms moved against positivism. The main tenets of post positivism (and where it differs from positivism) are that the knower and known cannot be separated and the absence of a shared, single reality.
- Postmodernism holds that facts are fluid and elusive, so that we should focus only on our observational claims.
- Constructionism considers how social phenomena develop in particular social contexts and how concepts appear to be natural and obvious to those who accept them, but in reality they are an invention or artifact of a particular culture or society.

The crucial debate is related to the question of what constitutes reality or rather if reality is objective or subjective. We consider three of those paradigms (that substantially differ in the perception of reality) in relation to epistemology and the methodology which derived (Table 12). The positivistic paradigm, very well known and largely applied, was formalized in the beginning of the 19th century; it originates from the idea of science developed during the Enlightenment period and it assumes that the scientific method (developed by Galileo Galilee) can be applied to all spheres of human knowledge and life. Typically physics applies the positivistic paradigm.

The post positivism mainly supported by Karl Popper considers human knowledge not based on unchallengeable, rock-solid foundations but rather conjectural; there are real

grounds and warrants for asserting beliefs or conjectures, although these warrants can be modified or withdrawn in the light of further investigation. Post positivism founds on the main consideration that the knower and the known cannot be separated; in this sense we have provided as example the Heisenberg uncertainty principle and the observer effect, examples derived from physics, methodologically resolved by applying experimental methodology but logically essentially stating that, in the act of observing, changes occurs on the phenomenon being observed[1]. Therefore reality exists but observations alter the possibility to capture reality in its completeness. Post positivism, ontologically speaking, is positioned between the positivism and constructionism paradigms.

The constructionism paradigm, developed in the second half of the 20[th] century, affirms that reality does not exist as universal and unique, but instead it is a mental construction; therefore multiple realities exist, according to the mental and sociological construction of each person. Following this stream of thought, provocatively, Andrew Pickering wrote the book "Constructing Quarks: A Sociological History of Particle Physics" in 1984.

As mentioned earlier, the theoretical paradigm held by each researcher influences the choice of the research methodology and even before, the nature of the posed questions, and possibly also the preference of the research field under investigation. Therefore, the theoretical frame comes prior to any research design and approach.

While valuing the positivist approach, conscious that the natural science disciplines found their validity and reliability in a rigorous scientific methodology, we also acknowledge that social sciences have strong difficulties in applying the positivistic frame. Our experience is that each individual perception presents many different aspects and facets and organizations, as sophisticated sets of individuals, relations and processes cannot be investigated with a scientific methodological approach, not in the sense of the positivistic paradigm. We do not state that reality does not exist but settings in which human beings are involved as researched entities and researchers, it is impossible to avoid any observer effect and prevent any bias derived from the interaction. In the case of the research field under investigation, the reverse supply chain, we believe that at best, it is possible to aim for a generic representation of the phenomenon and common observed development paths but already in the process of reaching a logical and coherent representation, an ongoing process aiming at simplification results in discharging some aspects. Furthermore, we do not believe that it is possible for the inquirer to reach a level of objectivity which assures complete distance. The qualitative

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[1] We may measure the position and momentum of a particle at the same time but if we increase the precision in measuring one quantity, we are forced to lose precision in measuring the other – Heisenberg uncertainty principle.

approaches adopted in social science research presents indications on how safeguarding against biases and to control the biasing effect.

	Positivism	*Post positivism*	*Constructionism*
Ontology	Reality exists out there (*realisms*) and it is driven by immutable, natural laws and mechanisms. Knowledge of these entities, laws and mechanisms is conventionally summarized in the form of time and context free generalizations. Some of their generalizations take the form of cause effects laws.	Reality exists but it can never be fully apprehended (*critical realisms*). It is driven by natural laws that can only be incompletely understood.	*Relativism (nominalism).* Realities exists in the form of multiple, mental constructions, socially and experientially based, local and specified, depending on their form, content and the persons who hold them.
Epistemology	*Dualism/objectivism.* It is both possible and essential for the inquirer to adopt a distant, non-interactive posture. Values and other biasing and confounding factors are thereby automatically excluded from influencing the outcomes.	*Modified objectivism.* Objectivity remains a regulatory ideal but it can only be approximated, with special emphasis placed on external guardians (warrants) such as critical tradition and the critical community.	*Subjectivism.* The inquirer and the inquired are fused into a single (monistic) entity. Findings are literally the outcome of the process of interaction between the two.
Methodology	*Experimental /manipulative.* Questions and/or hypothesis are stated in advance in propositional form and subjected to empirical tests (falsification) under carefully controlled conditions.	*Modified experimental/ manipulative.* Emphasize critical multiplism. Redress imbalances by conducting inquiry in more natural settings, using more qualitative methods, depending on more grounded theory and reintroducing discovery into the inquire process.	*Hermeneutic, dialectic.* Individual constructions are elicited and refined hermeneutically, and compared and contrasted dialectically, with the aim of generating constructions on which there is substantial consensus.
Examples	The physical gravitational law (Newton law).	– Heisenberg uncertainty principle – The observer effect – The famous experiment known as the Schrödinger's cat (the cat is supposedly neither alive nor dead until observed)	Andrew Pickering, Constructing Quarks: A Sociological History of Particle Physics, 1999.

Table 12 – Ontology, epistemology and methodology (adapted from: Arlbjørn and Halldorsson, 2002).

4.3 The Research Methodology

Supply chain management studies utilise a large variety of research methodologies. As it emerges from Chapter 2, methodologies vary from case study, survey, research hypothesis testing to quantitative modelling and simulation. While quantitative methodologies aim at representing and analysing the researched issue on mathematical terms, case studies, surveys and other social science research methodologies can include both quantitative and qualitative elements. Qualitative research is particularly suited in case of:

- The researched object is represented by exceptional persons or situations not in sufficient number to justify a sample for a quantifying study.
- The phenomenon of interest cannot be explained in isolation of its social complexity.
- There is the need to take into account multiple subjective perspectives.
- There is the need of analysing concrete cases in their temporal and local context: the interest is on "how", "why", "what" type of questions.

This thesis applies a qualitative research approach since at least three of the four previous points are present in the study: the phenomenon of interest cannot be explained in isolation of its social complexity, there is the need to consider multiple subjective perspectives, and the phenomenon can be analysed by using concrete cases and considering their evolution within a temporal and local context. Quantitative data are used to support the evidence gained with the qualitative analysis.

As Yin, 2003 states, the choice of the appropriate research methodology should be driven by:

- The type of the research question
- The control of the investigator over actual behavioural events
- The focus on contemporary as opposed historical phenomena.

The case study technique should be considered when:

 "a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control" (Yin, 2003).

Therefore, the case study is an empirical inquiry which aims at investigating real life context phenomenon, where the boundaries between the phenomenon and the context are not clearly evident. The definition given by Schramm, 1971 discloses another important aspect of case study research: "The essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what results". A

decision or a set of decisions is therefore under analysis and the only way to inform on the why, how and what of the decision is to conduct an empirical, real life context investigation.

In this research project, several conditions leading to a case study methodological approach are matched (Table 13).

Multiple case studies are suggested in the case of theory building research since multiple cases allow cross case analysis and they increase the validity of the findings (Eisenhardt, 1989). However, there is not an ideal suggested number. Eisenhardt, 1989 proposes a number between 4 and 10 in the case of case study research aiming at theory building. Yin, 2003 provides advantages and disadvantages of single and multiple case study research, without specifying what the ideal number would be, but in general opting for multiple case studies. In any case, a preliminary evaluation of the available time and resources should be performed since "…the conduct of multiple-case study can require extensive resources and time beyond the means of a single researcher investigator" (Yin, 2003).

Whenever possible, a research design that includes at least two case studies should be preferred to a single-case design. Even with two cases, there is the possibility to provide for replication. Replication is not synonymous of sampling. The logic supporting the use of multiple-cases aims at the theoretical generalisation in the sense of confirming similar findings (literal replication) or predicting contrasting results (theoretical replication). Therefore there are not similarities with the sampling logic applied in surveys aiming at statistical generalisation (enumeration of the entire universe or a pool of potential respondents significantly representing the entire universe).

To achieve theoretical generalisation, cases are chosen for replication, extension of theory, contrary replication and elimination of alternative explanations (Yin, 2003).

Summarising, the case study approach has always one or more of three main purposes (explorative, descriptive or explanatory), different applications (explain presumed causal links in real life observations, describe a real life fact and the context in which it occurs, illustrate certain topics, explore situations in which the interventions evaluated have not a clear set of outcomes) and it can be essentially used either for testing existing theory or developing new theory.

Type of questions	How and why questions. The research project aims at investigating : 1. How to configure the reserve chain; 2. Why the integration between the forward and reverse chain should be achieved; 3. In which conditions the reverse chain can be profitable.
Control of the investigator over the events	No control
Temporal focus	Contemporary, real life context events
Illuminate on a set of decisions	The reserve chain is analysed and investigated as it emerges in consequence of decisions and interactions between different actors over which the investigator has no control.

Table 13 – Conditions that justify the use of the case study methodology.

4.3.1 The Case Study Design

In this study, two cases that represent extreme contrasting situations have been deliberately selected, with the intent of describing and explaining observed causal links and thereby providing a theoretical general explanation (Table 14).

Purpose	Explanatory
Application	Describe and explain the presumed causal links
Final intention	Theory developing

Table 14 – The case studies purpose, application and final intention.

Preliminary interviews and literature review revealed the existence of two major drivers for reverse logistics (legislative and economic) that seemed to influence the configuration of the reverse chain and the possibility to integrate the forward and reverse flow.

Therefore the aim has been providing explanations for the different settings rather than seeking for replication: "In this type of research design, if the subsequent findings support the contrasts, the results represent a strong start towards a theoretical replication and … vastly strengthening the external validity of the findings…" (Yin, 2003).

The two case studies are represented by a legislation driven reverse chain and a value driven reverse chain.

The cases have explorative, descriptive and explanatory elements but the main purpose is providing explanations (explanatory). They are furthermore embedded: a case study is

considered embedded if multiple units of analysis are present within a larger unit of analysis. In both cases (Table 15), the largest unit of analysis embeds many smaller unit of analysis. The main unit of analysis is represented by the entire chain, and each chain is constituted by many different actors (companies, institutional organisms, trading and industry associations).

	Larger unit of analysis	*Multiple units of analysis*
Case study 1: the legislation driven reverse network	The reverse chain	Companies, institutional organisms, trading and industry associations.
Case study 2: the value driven reverse network	The reverse chain	Companies

Table 15 – The two embedded cases studies of the project.

At least one interview for each type of actor actively participating in the reverse process has been conducted. Table 16 reports all interviewed actors according to the typology and the country where the interview has taken place. Most of the interviews have been complemented with a site visit, direct observations and additional documentation.

	Type of actor	**Interviewed actors in Denmark**	**Interviewed actors in Italy**
Case study 1	Institutional organisms	The Danish Ministry of Environment, the WEEE–System	Center of Coordination RAEE
	Industry/sectors associations	LWF, Elretur, Nera, RE-DK	Ecodom
	Producers/importers	Bang and Olufsen, Bayer, Danfoss, Elgiganten, Nokia, Novo Nordisk, Zitech	Canon
	Waste management companies	Stena Technoworld H. J. Hansen Elektromiljø	Elettrorecycling
Case study 2	Producers/importers	ALPHABETA	
	Logistics provider	Geodis (Germany)	Geodis, DHL

Table 16 – Type and name of the interviewed actors for case study 1 and 2.

As previous literature pointed out that product characteristics influence the recovery practices, the cases focus on the reverse chain for electrical/electronic products. Electrical and electronic products are highly representative due to:

– the length of the technology cycle and wear out life (the shortening of product and technology life cycle),
– the complexity of the embedded technology which might cause significant failure frequency (returns for repair, returns for remanufacturing/refurbishing),
– the existence of specific legislations which impose recovery.

Products typologies for case study 1 and 2 are presented in Table 17.

Product typologies	
Case study 1	*Case study 2*
Large household appliances	Notebooks
Small household appliances	Desktops, stationary computers
IT and telecommunications equipment	CRT monitors
Consumer equipment	LCD monitors
Lighting equipment	Servers
Electrical and electronic tools (with the exception of large-scale stationary industrial tools)	Printers/Scanners
Toys, leisure and sports equipment	Ovens
Medical devices	Refrigerators
Monitoring and control instruments	Imagining devices
Automatic dispensers	

Table 17 – Product typologies for case study 1 and 2.

4.4 The Research Process

The research process is illustrated in Figure 12. The research started with a review of the reverse logistics literature. Along with the initial literature review we conducted a preliminary round of explorative semi-structured interviews with main producers affected by recovery legislations. These preliminary interviews were of great help in gathering basic information on behavioural patterns around the real "reverse world" and have been used in order to:

– Elaborate the research questions and structure the research questions in propositions. Yin, 2003 recognizes the strong value to the process of stating research propositions from research questions: besides reflecting important theoretical issues, study propositions help to delineate where to look for evidence to support the research questions.
– Validate the research propositions with relevant informed interviewees (logistics managers, regularity affairs attorneys, environmental engineers, and members of

trade and industry associations). The validation process has been used in order to prove the relevance of the researched issues.

– Support the research design process: case study selection, design of the protocol and interview guide, planning the data collection process. It soon emerged that the interview guide needed to be "shaped" differently according the type of interviewed actor, the role within his/her organisation and the role of the organisation in the reverse chain. The research protocol and the interview guide have been revised in collaboration with informed relevant interviewees and two researchers performing research on similar issues.

The following sections consider in detail the data collection process, the analysis phase and provide indications for quality testing.
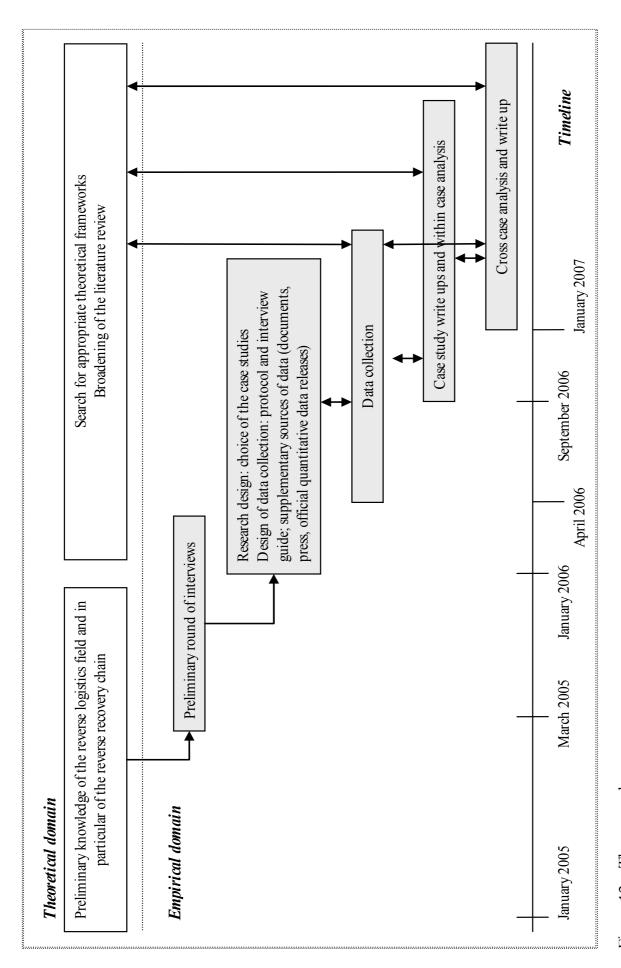
Figure 12 – The research process.

4.4.1 The Data Collection Process

Preparing for data collection involved two main stages:

– elaboration of the case study protocol;
– elaboration of the interview guide; interviews have been used as the major source of evidence, besides providing the opportunity for site visits and direct observations.

4.4.1.1 The Case Study Protocol

The study protocol is a major instrument for increasing the reliability of case study research and it should be designed in such a way that facilitates the data collection process. The protocol has been elaborated following the indications provided by Yin, 2003 which inform on the basic contents that a protocol should contain: an overview of the case study project, the field procedures, the case study questions, and a guide for case study reporting (Table 18).

Protocol	
Overview of the case study process	
Relevant readings	Literature review on supply chain management and reverse logistics
Objectives	Provide a general representation of the reverse chain; investigate the differences and similarities between the legislation driven recovery chain and the economic driven recovery chain.
General questions - questions to keep in mind while collecting the data	
– Is it possible to formulate guidelines, frameworks, operating models that can support firms in the process of adopting reverse logistics systems, regardless the industry in which the operate and the product they supply? Is it possible to suggest the right reverse supply chain according to the dismissed product? How to determine which recovery option better matches the disposed product? – The idea that producers manage their products from "cradle to grave" is often mentioned in literature to synthesise the concept of closed loop supply chains. Is it common to encounter such supply chain arrangements? In which conditions do the two flows really integrate and manifest clear existence of synergies? – What are the key factors that make product recovery an opportunity for profit generation? – How to measure reverse chain performances? What metrics to apply when considering both economical and environmental aspects?	
Field procedures: data collection	
Name of the site to be visited and contact person	
Data collection plan: establish the contact, verify availability, and plan the interview (eventual	

site visit). Preferably each interview/site visits should not cover more than half a day (eventual travelling time not included).
Prepare for the interview: visit company web site if available, evaluate relevant documents (environmental reports, returns procedures, reports on recovery targets). Whenever required, mail the questions in advance; ask in advance if the interview can be recorded.
Prepare the interview guide according to the interviewed actor (the same questions cannot be posed to a producer, an institutional organisation, a logistics provider, etc…).
Data collection stops when gathered information start to be repeated but at least one interview for each representative actor of the chain.
Eventually, agreement with respondent or company representative for using the material for publication purpose.
Case study reporting
Case study reporting framework: drivers, actors involved, processes, interfaces, treated products
Underline common patterns, divergent patterns
Use all sources of evidence: site visits, observations, obtained documents

Table 18 – The case study protocol.

4.4.1.2 The Interview Guide and the Interview Process

The interview guide has been designed according to the type of interviewed actor, the role within his/her organisation and the role of the organisation in the reverse chain. Preliminary semi-structured interviews have been used to refine the interview guide.

The first round of structured interviews performed in Denmark was conducted in order to provide a description of the relationships and the dynamics of the legislation driven reverse chain. The interviewed actors are part of the recovery chain of electrical and electronic equipment. The recovery chain has been established to comply with the European Directive on Waste of Electrical and Electronic Equipment (WEEE). A second round of structured interviews addressing the same type of actors was carried out in Italy in order to verify if countries specific issues could determine significant differences. These interviews were conducted as part of a serious of activities performed during the study period abroad. To build knowledge on the WEEE reverse chain has been a major task that has occupied most time dedicated to the data collection process and it has represented a major opportunity to gain experience and confidence for the second case study represented by the value driven reverse chain, which has been conducted and analysed in a much shorter time. For the second case study, interviews to logistics service providers and companies were conducted in Denmark as well as in Italy. All interviews were conducted in person and most of the time with the permission to record the interview. Only two interviews were carried out by phone with a remanufacturing unit placed in Germany.

Each interview lasted from 1 to 3 hours and at least one relevant person within each organisation was interviewed. The job title and the responsibility of the person/persons dedicated to reverse logistics could vary a lot (logistics manager, consultant for quality and environment, approval manager, WEEE project manager, take back and recycling manager, business development manager, reverse logistics division manager, environmental manager, etc…).

Whenever possible and relevant, the interview was complemented by a site visit (unfortunately permission to take pictures was never granted). In this case, the data collection process could take up to one entire day.

A total of 30 interviews were performed in 23 different organisations. All interviews have been transcript and coded. Appendix I presents in detail all the interviewed actors in Denmark and Italy for case study 1 and 2. Interview guides are included in Appendix II.

4.4.1.3 Other Data Sources

Interviews are subjected to bias, poor recall or inaccurate articulation (Yin, 2003); therefore it is a good strategy to complement the data collection process with other sources. Whenever possible, site visits and direct observations were conducted along with the interview. Company publication (annual and environmental reports) has been used to collect background information as well as reports issued by the European Community on environmental issues. Reports produced by other researchers have been used to complement the information.

4.5 The Analysis

Interviews often generated field notes registering impressions, ideas, and interpretations. In fact, field notes represent on ongoing stream of consciousness commenting what is happening in the research process and they generate the proficient frequent overlapping of data collection and data analysis. This overlapping is a key feature for research aiming at theories generation from case studies (Eisenhardt, 1989) since it does not only represent a start in the analysis but it allows to take the advantage of the flexibility of making adjustments during the data collection process. Overall, case studies allow collecting a large amount of data that has to be logically organised and there are not codified processes to move on from the data to the analysis (Yin, 2003) but in general it is suggested to proceed including a within-case analysis and a cross-case analysis.

4.5.1 Constructing the Case

One initial step has been simplifying the collected data using the transcriptions. Whenever accepted by the interested interviewees, transcriptions have been mailed for comments, additions, and changes. Each transcription has been analysed to search for answers to the research questions, identify interesting findings, emerging patterns and detect missing information needed to "reconstruct" the entire reverse chain in terms of processes and structure. The need to interview other actors in fact emerged during the data collection process.

Secondly, the interview transcriptions have been combined with the notes and other sources of information in order to produce preliminary reports that included relevant quotes from transcriptions. A total of 23 reports have been produced, corresponding to the number of interview actors. The same report has been mailed to the interviewees being part of the same organisation, asking for comments. While producing the preliminary reports, the interview guide evolved and in some cases, interviewees contacted in the early stages have been contacted again with new questions.

4.5.2 The Within-Case Analysis

This first part of analysis (within-case analysis) has aimed at outlining considerations and insights derived from the case study investigation and it has been preliminary to the cross case analysis. The within-case analysis has been conducted on the basis of a detailed description of each of the two cases and it has put in evidence the specific aspects of each reverse chain, downsides, limitations and strengths.

4.5.3 The Cross-Case Analysis

Combining within-case analysis with cross-case analysis allows registering emerging patterns. One tactic is to select categories or dimensions and then look for similarities and differences (Eisenhardt, 1989). The dimensions have been derived from the research constructs (propositions) elaborated from the research questions: e.g. the chain structure, the product residual value, the drivers, direct or indirect involvement of the actor on the reserve chain, role of the actor, profitability.

4.6 Validity and Reliability

Yin, 2003 suggests four tests that should support the quality of empirical social research: construct validity, internal validity, external validity and reliability.

Construct validity consists of establishing correct operational measures for the concepts being studied and in order to meet the test of construct validity two steps should be assured:

- Select the specific types of changes that are to be studied;
- Demonstrate that the selected measures of these changes reflect the specific changes that have been selected.

Three tactics are available to increase construct validity:

- Use multiple sources of evidence.
- Establish the chain of evidence.
- Have key informants reviewing draft case study reports.

All three tactics have been applied in this study. Multiple sources of evidence have been assured by complementing the interviews with site visits, direct observations, and company publication. Moreover, multiple informants have been used for both case studies. To verify the logic of argumentation, i.e., the chain of evidence, external reviewers have been engaged in reading the case studies write ups, the analysis and results. Furthermore, interviewees agreed to review interviews transcriptions and case reports.

Internal validity refers to establishing a causal relationship, whereby certain conditions are shown to lead other conditions. Therefore internal validity is relevant for explanatory (causal) case studies research where the researcher tries to determine that the event X led to the event Y. The main threats to internal validity are represented by spurious effects and the general problem of making inferences. The investigator might neglect that other events different than the event X, has led to Y. Therefore the inferring of X from Y should be properly documented. There are not specific tactics to achieve internal validity. Yin, 2003 suggests:

- Pattern matching which consists of comparing an empirically based pattern with a predicted one.
- Explanations building which founds on presuming a set of causal links.
- Addressing rival explanations.
- Logic models that should establish a complex chain of events.

Pattern matching has assured by:

- comparing conflicting and similar literature;
- confronting presumed patterns derived from a preliminary explorative round of interviews with the emerging and confirmed patterns derived from the second round of interviews.

Causal relations have been established by specifying the research questions in propositions and assuming causal links between the propositions.

External validity deals with the problem of knowing to which extent the study's findings can be generalised beyond the immediate case study. In analytic generalisation, the investigator strives to generalise a set of particular results to a broader theory. External validity can be provided by setting strong replication logic. Two cases do not represent strong replication logic but two cases that consider opponent settings can deductively provide indications for the intermediate settings. External validity has also been increased by data triangulation (company reports and third party sources of information).

The fourth test is the test for reliability where the objective is to assure that if a later investigator follows the same procedures as described by the earlier investigator and conducts the same case study, the later investigator arrives to the same findings and conclusions. Reliability can be assured by using a case study protocol and developing a case study database which consists of organised and documented collected data. A case study protocol has been developed. The material for each case in the database consists of:

- Interview protocol
- Recording of the interview
- Interview transcription and report
- Published company reports (environmental reports, annual reports)
- Case study write ups
- Email exchange with the interviewees
- Extra material provided by the interviewees (data, process descriptions, procedures, product descriptions, etc…).

As further step to increase objectivity, the interviews have been recorded and transcribed. It has not been possible to record two interviews since permission was not granted.

Social desirability refers to the respondents' tendency to give statements on the basis of the perceived acceptance of their actions. Social desirability can cause biases that can be reduced through the use of indirect questions during the data collection process (Kvale, 1996). Cultural differences are a known source of communication challenges. In this study, the respondents did not belong to many different countries, essentially two (Italy, Denmark and only in one case Germany) but with different cultural backgrounds. Gesteland, 2002 distinguishes between cultures that use indirect as opposed direct language. This difference causes misunderstandings between relationship-oriented and deal-oriented people. Deal-oriented people use direct language in order to be clearly

understood while relationship-oriented people use indirect language and the message is quite coded. According to Gesteland, Italians are moderately deal focused, Danish and German people are deal focused.

4.7 Conclusions

The chapter has presented the research design and the research methodology adopted for the case study investigation. The theoretical paradigm that represents the departing point for any researcher has been elaborated considering the main ontological approaches (realism, empiricism, positivism, post positivism, postmodernism, and constructionism), the epistemology and methodology which originate from the ontological view point.

The methodological choice has been motivated considering the nature of the investigated problem (the type of the research questions, the control of the investigator over actual behavioural events, and the focus on contemporary phenomena). The case study design has been unfolded presenting how the research process has been conducted, how cases studies have been selected and how the data have been gathered. The description of the process analysis (how analysis has been conducted) and how reliability and validity have been guaranteed completes the methodological frame.

The next two chapters present into details the two cases of this study, the legislation driven reverse chain and the value driven reverse chain. In Chapter 7 the two cases are analysed singularly (within-case analysis). Chapter 8 (cross-case analysis) considers to which extent the research propositions match the findings and elaborates a general framework based on the concept of the product residual value. Chapter 9 takes into consideration further possible explanations that the transaction cost and the institutional theory can provide to the analysis.

Chapter 5. The Legislation Driven Reverse Chain

> "The nation that destroys its soil destroys itself"
> Franklin Delano Roosevelt

5.1 Introduction

The consumption of electrical and electronic goods is increasing worldwide, as well as the speed at which they are released by the final users to the disposing market. Technological and functionality improvements continuously raise the replacement rate of this kind of appliance resulting in a growing amount of dismissed products which need to be properly treated and disposed of. Due to the negative environmental impact and the valuable material content, legislations imposing recovery have been approved by many different countries in the Western World as well in the emerging economies.

This chapter focuses on the legislation driven reverse chain that has been implemented in Denmark in order to comply with the European Directive on Waste of Electrical and Electronic Equipment (WEEE). The chapter unfolds one of the two case studies of this thesis, provides a detailed description of the chain, and actors involved. The first part of the chapter provides an excursion on the legislation driven recovery networks in general, presenting the main regulations approved worldwide concerning the treatment of solid waste and it ends focusing on the WEEE Directive, how it norms the recovery and recycling processes, and what products are affected. The chapter continues presenting the implementation of the Directive in Denmark; it describes the system at the institutional, configuration and operational level, the collective schemes, their structure and to which extent recyclers are involved in the chain. Some numbers related to the waste generation in Denmark are specified in order to value the importance of the

recovery flow. A short presentation of the implementation process undergoing in Italy in relation the WEEE Directive is also included.

We finally outline that the purpose of the case description presented in this and the following chapter is to help in identifying appropriate causal links to be analysed in the case analysis (Chapter 7) and in the cross case analysis (Chapter 8).

5.2 The Legislation Driven Recovery Networks

An increasing number of countries, states and municipalities are in the process or have already approved legislations and regulations related to the environment, addressing the problems of recovery, materials recycling as well as energy saving. All these regulations have contributed to enforce in the traditional logistics and supply context, the constitution of legislation driven recovery chains. In those chains, the producers, otherwise specified as original equipment manufacturers (OEMs), usually have legal responsibility for establishing, supporting and financing the recovery system while the recovery execution is in general outsourced to logistics service providers and specialised recycling companies, and often coordinated by industry associations. The design of the network aims at gaining low collection costs therefore collection locations are usually provided in cooperation with the municipal waste collection systems. Testing, grading and reuse tend to be neglected while recycling concentrates in removing hazardous substances and limited disassembly. In Boks et al., 1998 it is possible to find a comparison of implementation scenarios (collection, disassembly and mechanical processing) and legislations for EoL recovery networks in Japan, Western Europe and United States.

5.2.1 Legislations

Back in April 1991, the Federal Republic of Germany passed a stringent law on packaging and packaging waste that called for an increasingly larger percentage of the collected waste to be recycled and it legislated that incineration was not an option for disposal.

In 1997, the USA enacted about 80 recycling laws, while 25 countries already had producer responsibility laws for packaging and 13 required recovery of transport packaging (Stock, 1998). Since 1998, the White and Brown Goods Act in the Netherlands obliged manufactures and importers of electronic appliances to take back their products after use and recover certain minimum percentages. The Environmental Protection Agency (EPA) of Taiwan announced a Scrap Home Appliances and Computers Recycling Regulation in March 1998 (Shih, 2001). In September 2003, the State Environmental Protection Administration of China announced the enhancing of

the environmental management of WEEE and on the 29 December, 2004, the revised Law of People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste was approved by the National People's Congress and put into effect since 1 April 2005 (He et al., 2006). In 1998, Japan enacted the Japanese Recycling Law for Electrical Home Appliances, fully enforced by April, 2001 (Tasaki et al., 2005).

While differences exist in the financing and implementation mechanisms, all these legislations aim at reducing waste disposal, removing hazardous substances, and imposing minimum recycling targets.

The European Union has as well issued several directives on solid waste treatment:

- Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles;
- Directive 2005/20/EC of the European Parliament and of the Council of 9 March 2005 amending Directive 94/62/EC on packaging and packaging waste;
- Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC;
- Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment;
- Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment – WEEE[2].

5.2.2 The WEEE Directive

The WEEE directive – Waste of Electrical and Electronic Equipment – approved by the European Parliament the 27 January 2003 represents a full path to harmonisation and consensus among the European Member States. The material restrictions, the take-back and recycling obligations enacted through the WEEE directive strongly influences the EoL and EoU recovery policies of those products which are classified as electrical and/or electronic equipment (Table 19; a detailed list of the products for each of the product category is given in Appendix III).

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[2] Legislations texts are easily accessible at the European official website: http://eur-lex.europa.eu/en/index.htm.

1	Large household appliances
2	Small household appliances
3	IT and telecommunications equipment
4	Consumer equipment
5	Lighting equipment
6	Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7	Toys, leisure and sports equipment
8	Medical devices (with the exception of all implanted and infected products)
9	Monitoring and control instruments
10	Automatic dispensers

Table 19 - The WEEE product categories.

The purpose of the Directive is to prevent the creation of electrical and electronic waste and it promotes reuse, recycling and all the other forms of recovery in order to reduce final disposal. It encourages Member States to design and produce electrical and electronic equipment (EEE) which facilitates dismantling and recovery of components and materials. Furthermore, Member States should ensure that the treatment is undertaken by competent official approved operators that are regularly inspected. In relation to the WEEE from private households, producers can fulfil financial, recovery, treatment and disposal obligations individually or by joining a collective scheme. Furthermore, when placing a product on the market, they should provide a financial guarantee to prevent management costs of orphan products to load the remaining producers.

It is the responsibility of local Member State authorities to hold a register of producers and importers, and to collect information on an annual basis on quantities of categories introduced in the market, collected, reused, recycled, and recovered. This information should be reported to the Commission on a two-yearly basis and within 18 months after the end of the period covered. Table 20 reports the main WEEE implementation deadlines.

27 January 2003	The WEEE Directive is approved
13 February 2003	The WEEE Directive enters into force
13 August 2005	The systems should be ready to allow final holders and distributors to return WEEE waste from private households and users other than private household. Separate collection should be implemented (by ten product categories). Financial guarantee should be given (singularly or by participating into a collective scheme). The WEEE symbol (crossed out wheeled bin) should be placed on newly sold products and it must be visible, legibly and indelibly.
31 December 2006	Accomplishment of collection rate of 4 Kg/inhabitant per year. Accomplishment of recovery rates per appliances, reuse and recycling rates per materials, components and substances.
31 June 2008	The first reporting of Member States on WEEE compliance has to be delivered the European Commission.
31 December 2008	WEEE Directive revision: possible definition of new recovery/recycling rates and possible adjustments based on the Member States experience.

Table 20 – The WEEE implementation timetable.

At the moment of the study there were no reliable indications of the WEEE waste amount generated within the Member States, least of all, which of the two sources, households and industry, generates most of the WEEE. In late 1990s, estimations indicated to be 6.5-7.5 million tonnes per years the WEEE generated in Europe being the WEEE waste 4% of the municipal waste and expected to increase of 18%-26% every five years (European Commission, 2003). Recently the European Commission has issued a report that gives more detailed information on the amounts: across the EU27 (the 27 Countries which are part of the European Union), the WEEE waste is estimated to be between 8,3 to 9,1 million tones per years (data of 2005) and forecasts predict that by 2020, the total WEEE arising will annually grow between 2,5% and 2,7% reaching about 12,3 million tons.

The WEEE Directive has to be considered in relation with Directive 2002/95/EC on the restriction of the use of certain hazardous substances (HS) in electrical and electronic equipment which forces Member States to ensure that, from 1 July 2006, new electrical and electronic equipment placed on the market does not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE). PBB and PBDE are mainly contained in plastics therefore recycling companies are struggling to develop technologies that enable them to identify plastics which can be recycled (HS free) from plastics which cannot be reused.

5.3 The Implementation of the WEEE Directive in Denmark

The WEEE Directive came into force in Denmark the 1ˢᵗ of April 2006. By the 13ᵗʰ of August 2005, all producers affected by the Directive should have started to mark their products with the WEEE symbol.

We shortly give some particularities of the WEEE Danish implementation (details are in Danish Statutory Order no. 664, 2005). Demark decided to collect by five fractions: fraction 1 corresponds to category 1 and 10 of the Directive; fraction 2 to categories 2, 6, 7, 8, 9; the other fractions correspond to the same category number (Table 21). The grouping has been decided considering similarities in product structure and size.

WEEE Categories	1 and 10	2,6,7,8 and 9	3	4	5
Fractions	1	2	3	4	5

Table 21 – Correspondence between WEEE categories and fractions.

The final holder of EEE (Electrical and Electronic Equipment) from use in trade and industry placed on the market before 1ˢᵗ April 2006 shall provide for special treatment at an approved facility. For equipment placed on the market after 31ˢᵗ March 2006, producers/importers can sign agreements with the buyer in order to get the buyer assuming the responsibility; otherwise take-back service should be provided. No financial guarantee is foreseen for EEE from trade and industry.

For EEE placed on the market for use in private households after 31ˢᵗ March 2006, producers and importers shall provide an appropriate financial guarantee. Exceptions from providing financial guarantee are provided in the case producers are part of a collective scheme which counts more than 10 producers or 30% of the registered producers in one of the 10 categories and the market share of these producers counts for at least 30% of the total marketed equipments in that category.

For WEEE from private households, producers receive a share of the WEEE to be collected in proportion to their market share within each of the categories. An institutional agency, called WEEE-System is responsible to allocate the WEEE from private households that producers/importers are required to collect from the municipal waste collection stations. The WEEE-System is also responsible for the register and the registration process. The registration has been carried out from the 1ˢᵗ January 2006. Any other producer starting to market its products in Denmark should register at least 14 days in advance.

The Directive sets recovery targets which vary from 50% to 80%. These targets should be met by the 31ˢᵗ December 2006 and reported by the producers to the local authorities

by the end of year 2006. A three months period has been given to the producers in order to archive these data starting from the 1st of January 2007.

5.3.1 Involved Actors and Processes

The number and type of actors involved in the WEEE implementation and execution are various: governmental agencies (Ministry of Environment, Environmental Protection Agency), trade associations and collective schemes, consumers, importers, recyclers, transportation companies, etc… Each of them has different levels of responsibility. Actors, responsibilities and processes are presented at the institutional, configuration and operational levels.

5.3.2 The Institutional Level

At the institutional level, the Danish Government and Danish Ministry of Environment brought into force the Directive and appointed the WEEE-System responsible to hold the producers register, assign the collection of the waste on the basis of market shares, and manage the reporting system (recovery and recycling data aggregation and analysis). Once the data are aggregated, the Danish Environmental Protection Agency is responsible to report the data to the European Commission. The EPA is also responsible for the enforcement system. When coming to the network configuration, the WEEE-System has to provide all necessary information and the list of the approved collective schemes. Different rules apply to:

Case 1: the producer signs in the WEEE-System and implements its own take back scheme.

Case 2: the producer signs in a collective (compliance) scheme and the collective scheme signs its members in the WEEE-System.

In case 1 the producer is responsible to singularly provide for the collection and treatment of waste corresponding to its market share. In case 2, the producer signs a contract with a collective scheme. The contract specifies the fee paid by kilogram of recycled product; the fee covers the costs for the containers' renting, collection, transportation, and treatment (Table 22 gives indications of the average treatment costs by product category). It also states which agent performs the picking and transportation from the municipal collection stations, and the recycling company receiving and treating the WEEE waste. It finally regulates how recovery and recycling data are reported to the collective scheme.

Category	Treatment costs
1	0.026 €/Kg
	0.22 €//Kg for refrigerators/freezers, equipment with cooling unit
2	0.34 €/Kg
3	0.11 €/Kg
4	0.2 €/Kg
	0.32 €/Kg for Cathode Ray Tubes (CRT) appliances
5	0.6 €/Kg
6	0.3 €/Kg
7	0.3 €/Kg
8	0.32 €/Kg
9	0.11 €/Kg
10	0.03 €/Kg

Table 22 – Treatment costs per WEEE product category.

5.3.3 The Operation Level

At the operational level collective schemes, transportation companies, specialised logistics providers, waste management companies, final consumers, business users and municipalities act at different stages of the recovery process and with different responsibilities. In the Business to Consumers (B2C) context, the flow starts with the final user which is responsible for the proper disposal of the WEEE waste at the municipal collection stations. The waste is from there sorted into 5 fractions. The recovered products are picked and transported to the recycling plants. Consolidation precedes the arrival to the final treatment facilities. Picking and transportation are usually managed by recyclers with their own infrastructure or outsourced to logistics providers (most of the transportation is in fact outsourced). It follows the treatment. The waste can be exported and treated in recycling plants which are specialised for a certain type of WEEE fraction or exported to countries with lower labour costs (for labour intensive product recovery). Figure 13 represents the main steps from collection to the sale of recycled raw material.

The collective schemes coordinate all stages previous to treatment, handle the administrative tasks, and manage the relations with the national stakeholders (WEEE-System, EPA, and Ministry of Environment), the producers and all the contractors. Recyclers can as well be collective schemes. In this case, administration tasks and operational phases are performed by the same actor.
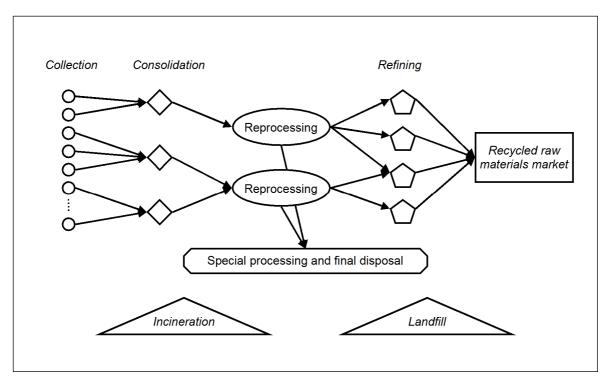
Figure 13 - The recycling processes in the B2C context.

In the Business to Business (B2B) context, there are several arrangements:

– The business user assumes producer responsibility in the buying contract, therefore the user provides for collection, transportation and treatment when the product is disposed.
– The business user rents or owns the containers for collection, places them at its premises and has a contract with a recycler for the collection and transportation. The business user pays for collection, transportation and recycling costs.
– The business user refers to the importer/wholesaler from which the goods were bought. The importer/wholesaler provides the disposing information and it usually arranges for collection and transportation.

In the B2B context, the collective schemes are not involved; the responsibility for reporting the recovery data to the WEEE-System is on the actor which assumes the producer responsibility.

5.3.3.1 The operation level for the B2C flow

Figure 14 illustrates the Danish collection and transportation system for a generic collective scheme in the B2C case.
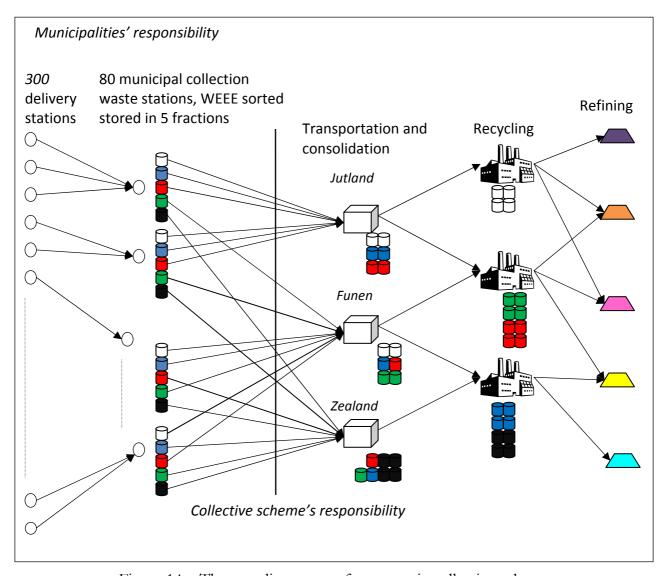
Figure 14 – The recycling system for a generic collective scheme.

In Denmark there are around 300 municipal delivery stations where the WEEE waste can be disposed. The stations are located in the three main Danish regions (Zealand, Funen and Jutland). The consumers (Denmark counts around 5.5 million inhabitants) deliver the WEEE waste to those delivery stations. Other forms of collection exist in areas with high population density. For instance, in Copenhagen, the municipality allows private users to deliver household appliances in the backyard of the residential buildings and the collection is performed by the municipality on average once a month.

At the delivery stations, the sorting of the WEEE waste into 5 fractions is carried out by the user or by the municipal personnel. The municipalities can decide how to sort and store the WEEE waste. They might have containers and cages at each delivery station or they can collect in bulk at the delivery stations, transport to a collection point and later sort the waste in 5 fractions. This is the most frequent collection system and it allows consolidating from 300 delivery stations to 80 municipal collection stations from where the waste is picked and transported to the recycling plants. Municipalities' responsibility

ends at the collection stations from where the waste is collected by the transporters contracted by the collective schemes.

Once the waste is collected, in most of the cases, it is consolidated once more before to be transported to the recycling plants (most of the Danish WEEE waste is treated at recycling premises located outside Denmark: Germany, Poland, Sweden, and Norway). Each transportation provider has its own consolidation policy but on average there is a consolidation point in each of the three main regions. Once the volume reaches a level that assures an efficient truck loading, the WEEE waste is conveyed to the recycling plants. The weighting is usually performed by the transporters; containers and cages are also weighted at the arrival at the recycling premises.

Roughly, the recycling consists of removing hazardous substances (for instance, the cooling unit is removed from refrigerators in order to avoid the dispersion of the cooling gas), treatment (the treatment varies according to the deployed recycling technology but, in most of the cases, all the waste is smashed using a shredder and materials are separated by magnetic field, air streams or other forms of separation). Valuable materials are sold to refining companies which enhance the purity level of the recovered materials. Refined materials are sold in the raw material market (for instance, recycling is at the moment the major source of copper since natural reserves are vanishing). All residuals which cannot be recovered are incinerated or sent to landfill disposal (Table 23 presents the main treatment operations per product type).

Input	Recovery Process	Output
Equipments containing CFC (cooling systems)	Manual operations: oil and mercury switches are removed. Then the body is processed on the shredder.	Metals, plastic, and glass are recovered. The rest is sent to landfill.
White goods	Manual operations: cables cut, asbestos removed, the rest is processed on the shredder.	Metals, concrete, plastics are recovered, the rest is sent to landfill.
Equipment with CRT (cathode ray tubes)	Manual operations: the back cover is removed, the cables are cut. The rest is processed by an audio-visual machine which removes printed circuit boards.	Metals and plastics are recovered. The batteries are sent to special treatment.
Lamps	First sorting according to the length using specific frames then the mercury is removed. Finally recycling is performed. The glass is crushed.	Glass and metals are recovered.
Household appliances	Batteries, asbestos and liquids are removed; the rest is processed on the shredder.	The batteries are sent to special treatment. Iron, aluminium, copper, alloys, plastics are recovered. The waste is only 1% of the total weight.
IT equipment	Circuit boards and batteries and LDCs are removed, drivers are smashed; the rest is processed on the shredder.	The batteries are sent to special treatment. Iron, aluminium, cupper, and alloys are recovered. The waste is only 1% of the total weight.

Table 23 – The treatment of the WEEE waste.

5.3.4 The Collective Schemes

Out of the 1024 electrical and electronic importers and Danish producers signed in the WEEE-System and operating in the B2B and/or B2C markets, 151 (around 15%) have implemented their own take-back program, but only one of them operates in the B2C market (Table 24). The other producers participate in a collective scheme which might be:

Industry specific as in the case of LWF (The European Lamp Companies Federation – ELC), which groups 30 companies and importers of light equipment. In Denmark it has been established by GE lighting, OSRAM, Philips and Sylvania.

Generic as in the case of Elretur, NERA (The Nordic Electronic Recycling Association), and RE-DK.

NERA and RE-DK have been established in 2006 therefore they count for a limited number of members. All data refers to the end of 2006.

	B2C	B2B	SUM
	Number of companies that have signed only in the WEEE-System		

	by market type		
WEEE-System	1	150	151
	Number of companies that have signed in a collective scheme		
COLLECTIVE SCHEMES			
LWF	30	-	30
NERA	10	-	10
Elretur	825	-	825
RE-DK	3	5	8
SUM	867	155	1024

Table 24 – Number of registered companies by collective scheme and market type (source: WEEE-System).

Each collective scheme is described in detail.

Elretur is the first collective scheme that has been created in Denmark, and mostly for this reason it counts for a lot of members. It deals with all five fractions, and at the moment it accounts for 825 members, a total of about 65% of WEEE market share. The scheme performs all administration and coordination tasks and does not own any of the collection or treatment infrastructure. Therefore it negotiates contracts for 3 years periods with 5 different recycling companies in order to provide collection, transportation and treatment of its WEEE market share. The recycling contractors are: Uniscrap A/S, DCR Miljø A/S, Averhoff A/S, Stena Techno World A/S, H.J.Hansen Elektromiljø A/S. Figure 15 depicts the division of the Danish territory in 5 areas: north of Jutland, center of Jutland, south of Jutland with Funen, south of Zealand, north of Zealand with Borholm. Each area has its own contractor for each fraction.

LWF was established by the Danish lamp Industry Association and it is the only industry specific collective scheme operating in Denmark. It manages operations in connection with the collection and recycling of lamps and luminary waste (fraction 3) for its market share. As in the case of Elretur, the scheme does not own any infrastructure and it subcontracts all operations. Table 25 and Table 26 show the recycling contractors and the transportation contractors according to the regions.

Zitech is a large Danish retailer and the only company operating in the B2C market which runs its own take back system. It employs its own cages, containers and trucks for collection and transportation.

NERA operates in Denmark and Finland. In Denmark it was established by 6 of the major electric and electronic equipment producers and retailers: ElGiganten, HP, Ingram Micro, Egmont, Sony Ericsson and Braun. At the moment it counts 8 members. It is the

recycling company called Stena, which on behalf of NERA takes care of the whole recycling chain: logistics, recycling, reporting, invoicing and administration.

Figure 16 depicts the consolidation and transportation processes while Figure 17 reports where the different treatment operations for WEEE waste are performed.

RE-DK which at the moment counts only 3 members was officially established in October 2006. It is also supported by a recycling company, H.J. Hansen. There is no data available on the consolidation and recycling sites.
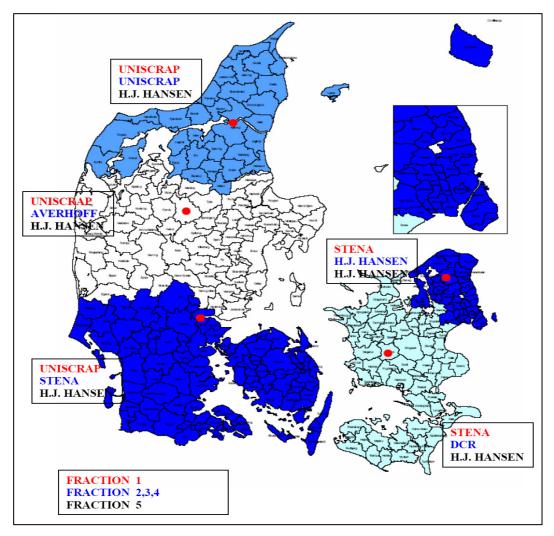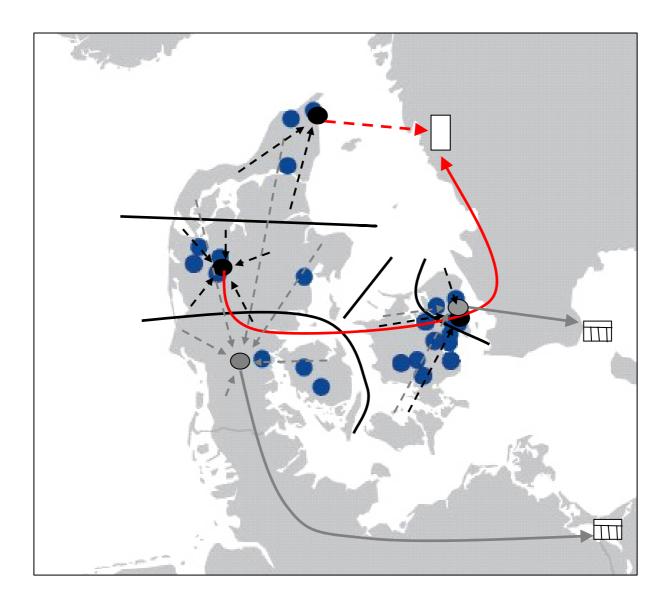
Figure 15 - Elretur contractor recyclers according to collection zones.

Region	Recycling
Zealand	H.J. Hansen
Funen	Stena
Jutland	H.J.Hansen

Table 25 – LWF recycling contractors.

Region	Logistics
Copenhagen area	H.J.Hansen
Zealand	H.J.Hansen
South Jutland/Funen	Stena
Center of Jutland	Stena
North Jutland	Stena

Table 26 – LWF logistics contractors.

●	Light and display appliances local recycling in Frederikshavn, Herning and Roskilde. Local Stena consolidation site for cooling appliances	
▯	Cooling appliances transported and treated in Halmstad, Sweden	→ (red)
▥	Cages transported to Brakne-Halstahammar, Sweden or to Poznan, Poland	→ (grey)
◖	Local Stena consolidation sites for cages	

Figure 16 – Stena's consolidation and transportation processes.
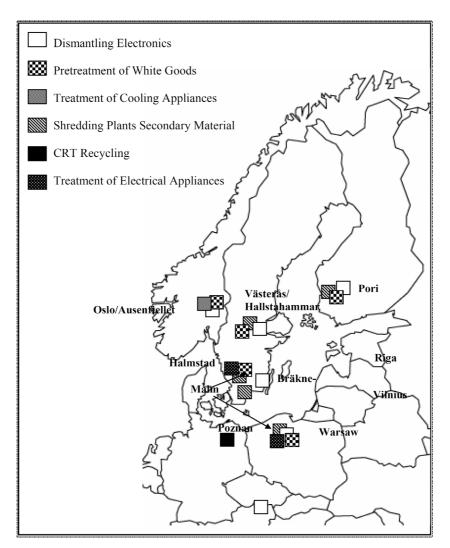
Figure 17 – Stena's plants for pre-treatment, treatment, shredding and recycling.

5.3.5 The WEEE waste in Denmark: some figures

The Directive has left the possibility to producers and importers to form and operate individual and collective take back programs. Most of the time, industries/sector specific or generic collective schemes have been formed. In Denmark there is only one case of an individual take-back system in the B2C market. During the second half of 2005, the WEEE recovery chain was planned and implemented for the first time by using the sales records of each producer. We underline that the allocation of the collection sites have been guided by sales data which might very much differ from the real collected volumes. Nevertheless, in the planning phase, the sales data represent a satisfactory approximation of the expected collected volumes when there are not known data of the collection volumes of the previous year. In addition, planning according to the sales data guarantees that the fee paid by the producers largely covers the costs of collection,

transportation and treatment, since sales volumes exceed collected amounts in any newly implemented WEEE recovery system.

The following data represents the market shares by category and by each collective scheme used in the allocation process in Denmark in 2006. The data are in millions of kilograms and percentages (Table 27).

Millions of kg (2006)	1	2	3	4	5	6	7	8	9	10
Scheme 1	10	10	5	5	0,05	0,4	0,1	0	0	0
Scheme 2	0	0	0	0	0,5	0	0	0	0	0
Scheme 3	6	7	4	1	0,2	0,1	0,3	0,5	0,2	0
Scheme 4	0,2	0,4	0,25	0,25	0,2	0,05	0,02	0,04	0,025	
Scheme 5			0,5	0	0	0	0	0	0	0
SUM	16,2	17,4	9,75	1,75	0,95	0,55	0,42	0,54	0,225	0

% (2006)	1	2	3	4	5	6	7	8	9	10
Scheme 1	62%	57%	51%	29%	5%	73%	24%	0%	0%	0%
Scheme 2	0%	0%	0%	0%	53%	0%	0%	0%	0%	0%
Scheme 3	37%	40%	41%	57%	21%	18%	71%	93%	89%	0%
Scheme 4	1%	2%	3%	14%	21%	9%	5%	7%	11%	0%
Scheme 5	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%
SUM	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%

Table 27 – The market shares of each of the five collective schemes.

The category amounts by collective scheme represent the amount of WEEE waste that is assigned to the collective scheme for collection, transportation and treatment. The total category amounts are converted into 5 fractions. Table 28 provides the total amounts for each collective scheme, both in kilograms and in percentage for year 2006.

kg (2006)					
Fraction	1	2	3	4	5
Category	1+10	2+6+7+8+9	3	4	5
Scheme 1	10,000,000	10,500,200	5,000,000	500,000	50,000
Scheme 2	0	0	0	0	500,000
Scheme 3	6,000,000	8,100,000	4,000,000	1,000,000	200,000
Scheme 4	200,000	535,000	250,000	250,000	200,000
Scheme 5	0	0	500,000	0	0
SUM	16,200,000	19,135,200	9,750,000	1,750,000	950,000

% (2006)					
Fraction	1	2	3	4	5
Category	1+10	2+6+7+8+9	3	4	5
Scheme 1	62%	55%	51%	29%	5%
Scheme 2	0%	0%	0%	0%	53%
Scheme 3	37%	42%	41%	57%	21%
Scheme 4	1%	3%	3%	14%	21%
Scheme 5	0%	0%	5%	0%	0%
SUM	100%	100%	100%	100%	100%

Table 28 - Total amounts in kilograms and percentage, year 2006.

Table 29 reports the kilograms by inhabitant to be collected.

Fraction	1	2	3	4	5
Kg by inhabitant	3.08	3.64	1.85	0.33	0.18

Table 29 – Kilograms by inhabitant by fraction.

The actual collected volumes for the year 2006 reported to the Danish Ministry of Environment at the beginning of year 2007 are presented in Appendix IV. From the data it emerges that Denmark has reached and surpassed the target collection volume of 4 Kg/inhabitant imposed by the WEEE Directive.

5.4 A Confrontation with the Italian Implementation System

At the moment of writing, Italy has not gone further than the planning phase. Beside, the WEEE Directive has not been transposed yet into local national legislation. Therefore benchmarking is limited to the planning phase.

The Italian National Government has approved a legislative decree that sets the conditions for the producers' national register, the modality for registering and updating the register. The equivalent of the WEEE-System in Denmark, the Center of Coordination, located in Milan, should give indications for the implementation of the WEEE recovery system to all actors involved, and represents the referent institution for the collective schemes. The Center of Coordination should also monitor how the WEEE waste is collected and transported, the conditions of the collection points and the compliance to the environmental obligations. As in Denmark, the Center of Coordination acts as the linkage between the collective schemes and the Ministry of Environment for the annual reporting of data related to collection, treatment, landfill and incineration. The Center of Coordination is also in charge for the allocation of the collection sites to the collective schemes.

As in Denmark, the collective schemes are industry specific or offer general services for all products categories. Collective schemes vary be pure administrative, driven by to providers/treatment companies or logistics service. There are limited indications of the possible market shares of each collective scheme. At the moment of writing, the registered collective schemes are 9 and the projected market shares are presented in Table 30. The Italian system has also aggregated the 10 product categories in 5 fractions.

Most of the problems related to the Italian implementation process are of political nature. The current and previous Italian Governments have given very limited attention to environmental legislations. The latest national legislation which regulates all waste related issues is dated back to 1997 and the legislative indications given to the municipalities are in contrast with the role that municipalities should have in the WEEE recovery system.

All actors involved have been discussing for long the possible configurations of the WEEE recovery system but there is not any authority that has the necessary power to impose a decision and overcame individualistic interests to guarantee a recovery system which is efficient and effective. Furthermore, the wholesale and retail sectors are expressing strong opposition to the one-to-one basis principle that would allow consumers to return items when buying a new one. Wholesalers and retailers are trying to avoid investing in the necessary warehouse space to store the returned products. In addition, there is not a census of the municipal collection stations suitable to receive the WEEE waste and a deficit of treatment facilities (mainly in terms of proper technological assets and geographical distribution, since most of the treatment plants are located in the northern regions of the country). Even though producers have engaged in the establishment of compliance schemes and the Center of Coordination has signed contracts in order to design and develop the IT system that should support the allocation of the picking calls to the collective schemes, there is not a common will to

move further in the implementation and no clear indications of the responsibilities of each actor.

	Fraction 1	Fraction 2	Fraction 3	Fraction 4	Fraction 5
Collective schemes					
Ecodom	60%	80%	0%	3%	0%
Re.Media	5%	0%	59%	25%	0%
Ecolamp	0%	0%	0%	1%	94%
ERP	23%	20%	32%	31%	0%
Ridomus	5%	0%	0%	0%	0%
Ecoped	0%	0%	0%	20%	0%
Ecolight	0%	0%	0%	4%	6%
Ecorit	7%	0%	9%	12%	0%
Ecosol	0%	0%	0%	4%	0%
	100%	100%	100%	100%	100%

Table 30 – Projected market share for each compliance scheme.

1	Ecodom	Fractions 1,2,4
2	ERP	Fractions 1,2,3,4
3	Ecolamp	Fractions 4,5
4	Re.Media	Fractions 1,3,4
5	Ecorit	Fractions 1,3,4
6	Ecoped	Fraction 4
7	Ecolight	Fractions 4,5
8	Ridomus	Fraction 1
9	Ecosol	Fraction 4

Table 31 – The fractions that each compliance scheme administers.

5.5 Conclusions

The chapter has presented one of the two cases considered in this thesis: the legislation driven reverse chain. The legislation that has determined the planning and implementation of the reverse chain is a European Directive which forces producers to recover dismissed electrical and electronic products.

The Danish implementation of the Directive has been presented in detail as well as the recovery flow.

The thesis particularly considered the implementation of the B2C flow which is characterised by the following stages:

– The WEEE-System assigns the collection points to the collective schemes according to their market share.
– The municipalities manage the initial collection and sorting and they interface with the transporters to arrange the picking.
– The logistics providers supply the transportation means, plan the routings, determine the consolidation policy and plan the shipments to the recycling plants.
– The recyclers register the weight and type of the incoming waste and treat the waste.
– The collective schemes administrate the flow from the municipalities to the recycling plant.

The implemented system presents several inefficiencies which will be discussed in the case analysis (Chapter 7).

Chapter 6. The Value Driven Reverse Chain

"The goal of life is living in
agreement with nature"
Zeno

6.1 Introduction

This chapter presents the value driven reverse chain of this study. The case is based on a series of interviews conducted with Geodis, a logistics service provider which offers both forward and reverses logistics services. The chapter focuses on the reverse logistics processes and it particularly considers two reverse flows:

– Remanufacturing/refurbishment of PC equipment. Remanufacturing is performed centrally in Mainz for dismissed products collected in 15 European countries. The centre is almost completely dedicated to one single customer, which we call for anonymity Alphabeta.
– The pre-treatment of end-of-utilisation products in Busnago, Italy. On the contrary to refurbishment, the pre-treatment service is performed for different customers all located in the Italian territory.

The two flows can be considered as two different instances of the same value driven reverse chain which has Geodis as the focal company and main chain actor. We highlight that the two flows present consistent distinctions: while refurbishment is centralised, dependent on product typology (PC equipment) and customer dedicated, pre-treatment is to some extent decentralised (the Italian site is only one of the Geodis sites which perform this process), partially product typology dependent and not customer specific (Gobbi and Halldorsson, 2007).

6.2 Company Description

The company is the major French logistics provider and the fifth in Europe. It started to operate 12 years ago in France and since then it has expanded both geographically and in the logistics services portfolio: distribution (groupage and express), logistics, full and part loading, air and sea freight, and reverse logistics for the business sectors of automotive, consumer goods, healthcare, chemicals and gas, retail, high tech industry, press, textile and luxury goods. It counts 23.800 employees worldwide, around 70.000 customers, 500 sites, 17.000 vehicles and total annual revenue of around 32 million Euros and increasing over the last few years. It is quoted on the French stock exchange market and the main shareholder is the French national railway system. The company has engaged in reverse logistics almost from the beginning of its history. At least in Germany, 15 to 20% of the business is represented by reverse logistics services. Recycling and remanufacturing are almost equally split (50-50%). Geodis cooperates with the ERP (European Recycling Platform) for the design, implementation and coordination of the recycling operations of end-of-life products in France, United Kingdom, Ireland, Spain and Portugal in relation to the implementation of the WEEE Directive.

6.3 Remanufacturing

The dedicated site in Mainz performs the remanufacturing and refurbishment of PC equipment. It has 4.500 m² of warehouse space and service space, around 85 permanent employees and 60 temporary. Temporary employees are engaged when the site has to effort picks of work load. The centre (called Central Asset Recovery Center - ARC) is a certified recycling organisation (ISO 14001).

The total volume treated yearly is 200.000 units with an average weight of 13 kilograms. Out of the 200.000 units, 165.000 are refurbished, 35.000 dismantled and scrapped. 60.000 parts are harvested from the scrapped fraction. The monthly load is around 16.000 units but the required capacity can vary from month to month, with periods of large picks and shortages. Table 32 reports the data for year 2006.

Total volume per year	200.000 units
notebooks	32%
desktops	30%
CRT monitors	18%
LCD monitors	7%
Servers (INTEL based)	5%
Printers/Scanners	8%

Table 32 – Total processed volume and percentages of different products type.

The ARC is 99.9% dedicated to the customer Alphabeta and therefore the remanufacturing process is very much dependent on Alphabeta requirements in terms of performances and contract service level agreements. Alphabeta has as its core business the leasing of IT products to business users. The leasing contract can be for Alphabeta products as well as products of other manufacturers (Dell, Toshiba, Siemens, HP). In 2006, 45% of the remanufactured products were Alphabeta branded products; the rest was represented by other brands. The percentages of the other brands can vary a lot according to the expired leasing contract. Figure 18 reports the volumes treated since 1997 for the Alphabeta customer.

**Volumes Remanufacturing PC Products
Asset Recovery Center Mainz**

	1997	1998	1999	2000	2001	2002	2003	2004	2005
□Units	2.647	15.889	33.926	40.932	44.193	109.094	203.327	190.580	207.883
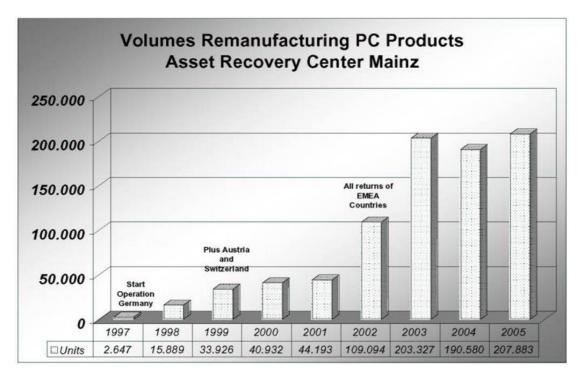
Figure 18 – Volume trends since 1997.

Geodis is in charge of collecting dismissed products whenever Alphabeta signs a new agreement with its customers. The deployed remanufacturing technology is nearly the same for all brands. Large differences are registered in processing CRT and LCD monitors since the manufacturing technology is completely different.

The site is the former Alphabeta recovery centre for Germany. In 2002, Alphabeta signed with Geodis, a pan European action reverse logistics program releasing parts of its refurbishment/remanufacturing operations. The Alphabeta recycling unit is still located near the Geodis recovery assets centre representing a typical case of supplier-customer co-location: scrapped materials from the ARC (Geodis) are easily conveyed to the recycling facility (Alphabeta).

According to the service level agreement, the total lead time to perform the complete process (picking, transportation, receiving, testing, errors reporting and refurbishment) is 12 days. 12 days is the time that Alphabeta needs to close the leasing contract with its customers and the closing of the contract is related to the returned product conditions. Status, damages, inappropriate use can only be detected during testing, dismantling and repair. Therefore within 12 days Geodis has to deliver to Alphabeta the information related to receiving, serial number registration and repair. The 12 days are counted from collection at the customer site to order closed. Order closed means that testing has been performed, errors and damages have been identified and registered, and the machine is sent to repair or either to dismantling. Out of the 12 days, 7 days are for collection, transportation, and receiving, 5 days all the other operations. Within 14 days, the refurbished products have to be available in the storing area, packed and ready to be shipped. Figure 19 represents the process flow.

| Order | Customer arrangement | Collection & Transportation | Technical activities | Reselling by Alphabeta | Preparation & Put at Disposal |
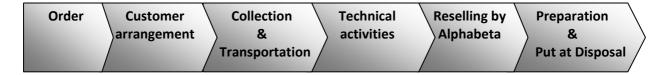
Figure 19 – Inbound, refurbishment and outbound processes.

The refurbishment of large size products is directly performed by Alphabeta in other sites in Europe (one is located in Montpelier, France). In this case Geodis provides the transportation service from the customer site to the country hub where the decision of reworking, remanufacturing or scrapping is taken on the basis of the serial number. Further transportation is guaranteed and the destination depends on the chosen recovery option (scrapping or reworking). In this case, early evaluation based on serial number identification determines the recovery option and therefore the subsequent stages the product undertakes in the reverse chain.

6.3.1 The Inbound Process

Geodis is in charge of collecting dismissed products whenever Alphabeta signs a new agreement with its customers. The inbound logistics has to ensure collection from Alphabeta customers' sites in Europe, intermediate consolidation and delivery to the Recovery Asset Center in Mainz. Alphabeta communicates to Geodis on a regular basis the leasing contracts due to expire within the next 30 days. The communication holds customer name and picking location.

It is Geodis that makes contact with the customer and arranges the picking. An integrated track and trace system allows Geodis and Alphabeta to follow the entire

inbound logistics process for each picking and for the 15 European countries serviced by Geodis. The transportation service is partly performed by Geodis and partly outsourced, depending on the transportation infrastructure capacity deployed in each country. In France, for instance, the total transportation and warehousing capacity owned by Geodis allows to perform all the inbound processes. The consolidation phase is very crucial when the transportation service is not outsourced. Picked volumes are consolidated in the local country hubs before to be delivered to Mainz. However, truck loading optimisation has to be balanced with time dependent constrains: returned products are subjected to a loss of value of 2-5% a month and the contract does not allow more than 14 days from picking to order closed and product repacked.

Typology and conditions of the shipped products are not known in advance and no check is performed at the customer site. Geodis receives general information on the expected number of pallets and product group (for instance servers) but not on the quantity, type or conditions. What is received can be different from what is expected since customers, exploiting the fact that returned products are not checked at picking, give back other equipment which is not part of the leasing contract.

At the moment of receiving, the shipment is registered as well as the equipment serial numbers. All machines are subjected to a verification test (AVT – Asset Verification Test) for functionality, configuration and cosmetics check. The AVT is performed by using individual developed aligned software. A fault reporting system is used to register and identify errors and defects. The error codes are registered at the end of the AVT.

The registration allows Geodis and Alphabeta to follow the entire process from receiving to order closed. After receiving, data wiping and hard disk (HDDs) impairment is performed in order to comply with Alphabeta requirements. Irreversible data wiping are assured in accordance with the German Data Protection Act and US Military Standards, and certified by the inspection authority. HDDs are physically destroyed by drilling. Magnetic fields of the intensity of 1 Tesla are used to completely erase HDDs, disks and tapes.

6.3.2 The Refurbishment

Refurbishment is performed by using parts harvested from defective machines. 20% of the received equipment is dismantled and scrapped due to:

- bad cosmetics conditions
- incorporated technology not longer required by the market
- denied authorisation for refurbishment due to exceeding repair costs.

Therefore there is no need to supply the refurbishment process with externally acquired components. On the contrary, half of the harvested parts are used for refurbishment in Mainz, half are sent to a central warehouse in Netherlands and used by the European Alphabeta repair network. It is up to Geodis to decide which parts are kept for internal use and which parts are sent to the spare parts warehouse in the Netherlands unless Alphabeta expresses a specific request for needed parts.

Machines which are not repaired are dismantled, valuable parts are harvested, and remaining components are sorted in different potential recyclable metal fractions and harmful substances. Hazardous substances are sent to the disposal area. Disposal is carried out in accordance with the Waste Avoidance and Management Act, Waste Management Facilities Regulation and WEEE. Recycling is performed in collaboration with certified waste management facilities.

The refurbishment process consists of repairing, cleaning, and upgrading with high quality components and software installation. Final packaging can follow according to customer needs. Remanufacturing operations are product specific (only PC equipment) but quite flexible regarding the range of refurbished products. Due to the fact that incoming product type is not known in advance, flexibility is crucial in planning the remanufacturing capacity. 42 work stations are able to handle each product type. If possible, each shipment is kept together since it is crucial to guarantee the same lead time for all equipment belonging to the same shipment. Of course this depends on the shipment volume: shipments of 1000 units cannot be processed at the same work station respecting the lead time.

The work station capacity is related to the processed product type: roughly, between 40 and 50 monitors can be processed during one work shift (8 hours), around 25 notebooks, and on average 30 desktops. LCD monitors require the smallest effort while servers require the longest processing time. The biggest challenge is in fact to plan correctly the capacity within short time frames, both in terms of work stations and operators' capacity. The refurbishment operations are instead easily performed due to high experience and knowledge of the processed products: product structure, parts/component accessibility and needed tooling are known.

6.3.3 The Outbound Process

After refurbishment, the machines are stored in the warehouse. Assets are always Alphabeta property during the overall process and it is Alphabeta responsibility to remarket the refurbished products via a brokers' network. Brokers have to be certified and they have to comply with specific Alphabeta requirements. Remanufactured products are sold all over the world, but mainly in Europe and only to business users.

Figure 20 represents the entire process from receiving to reselling via the brokers' network.
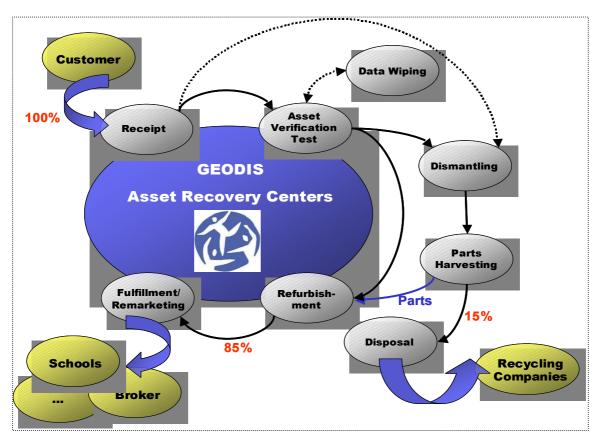
Figure 20 – Representation of the process flow (for the kind concession of Geodis Deutschland GmbH, MAINZ, Asset Recovery Center).

6.4 Disassembly and Recovery

The Geodis unit in Busnago, Milan operates uniquely for the Italian market. The site performs mainly disassembly of servers, stationary computers, and printers. Other products as refrigerators, ovens, and imagining devices are occasionally treated.

The site is mainly dedicated to the phases which come before recycling: dismantling, parts/components harvesting and materials separation. The output which can be waste, recyclable materials and metals is conferred to specialised refining, melting plants or waste treatment plants. Part of the operation involves refurbishment of valuable parts or entire machines that can be remarketed. Occasionally the centre acquires defected lots of electrical or electronic products from the market and the goods are repaired and resold.

The core service, disassembly and parts harvesting, is offered to a diversified customers' panel: customers are business users and IT producers. The main customers are IBM, Banca Intesa-Sanpaolo, Samsung, Dade Behring, Vodafone, Cisco, Electrolux. Customers' contracts are signed yearly. Since the customer payment already covers all costs for collection, transportation and dismantling, additional profit is generated when the equipment can be repaired and resold.

The total processed volume is around 3.000.000 kg/year. Table 33 and Table 34 report input and output material for the year 2006. Discrepancies between input and output are due to stocks accumulated in the previous reporting period. Input and output are categorised according to the European Waste code since all equipment is acquired as waste. The input is represented by discharged equipment, parts, components and packaging material. Volumes and weight of treated products can vary a lot: PCs of 30x25x2 in dimensions, and weight of 4 kg; metal racks of 60x60x200 and weight of 150 kg; cash flow machines of 100x100x250 and weight of 500 kg.

The major part of the input is recovered as:

- Refurbished machines. Returned defect lots are bought from the market (producers, wholesalers, and brokers), repaired and remarketed.
- Remanufactured and remarketed components/parts. Remanufacturing involves memory cards, hard disks, monitors, and keyboards that are evaluated according to conditions and market request.
- Components consigned to specialised melting plants: gold, silver, palladium are recovered from boards and connectors by blast furnace melting.
- Material consigned to refining plants and recovered as second raw material (plastic, paper, wood, glass, non precious metals).

The remaining part is sent to waste disposal (incineration and landfill). Figure 21 reports the recovered percentages from May to December 2006.

Input in 2006 (in Kg.)		
European Waste Code	Description	Quantity
15.01.01	Paper and cardboard packaging	57.522
15.01.02	Plastic packaging	28.622
16.02.13*[3]	Discarded equipment containing hazardous components[4] excepted transformers and capacitors containing PCBs and discarded equipment containing free asbestos	279.657
16.02.14	discarded equipment other transformers and capacitors containing PCBs and discarded equipment containing free asbestos	1.988.747
16.02.15*	hazardous components removed from discarded equipment	17.050
16.02.16	components removed from discarded equipment	217.332
17.04.05	Iron and steel	92.640
20.01.01	Paper and cardboard	286.466
20.01.35*	discarded electrical and electronic equipment containing hazardous components other than fluorescent tubes and other mercury-containing waste and discarded equipment containing chlorofluorocarbons	4.085
Total		2.972.121

Table 33 – Input in 2006.

Output in year 2006 (in Kg.)						
European Waste Code	Description	Delivered to melting	Recovered second raw material	Remarketing of parts and components	Conferred to refining companies	Waste disposal
8.03.18	Waste printing toners with no dangerous substances				11634	
12.01.05	Plastics shavings and turnings		77.980			
15.01.01	Paper and cardboard packaging		168.910			
15.01.02	Plastic packaging		47.790		12.504	
15.01.03	Wooden packaging		40.020		81.580	
15.01.06	Mixed packaging					139.31
15.01.07	Glass packaging		11.120			
16.02.13*	Discarded equipment containing hazardous components excepted transformers and capacitors containing PCBs and discarded equipment containing free asbestos				42.342	
16.06.01*	Lead batteries				29.215	

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[3] * indicates waste containing hazardous substances.

[4] Hazardous components from electrical and electronic equipment may include accumulators and batteries marked as hazardous; mercury switches, glass from cathode ray tubes and other activated glass.

16.06.02*	Ni-Cd batteries				1.222	
17.04.02	Aluminium		53.680			
17.04.05	Iron and steel		1.400.740			
17.04.07	Mixed metals		75.620			
17.04.11	Cables not containing oil, coal tar and other dangerous substances		42.870			
20.01.01	Paper and cardboard		322.570			
20.01.21*	fluorescent tubes and other mercury-containing waste				1.106	
20.01.23*	discarded equipment containing chlorofluorocarbons				650	
20.01.36	discarded electrical and electronic equipment	67.371				
Parts	Functioning Parts and components recovered from waste of electrical and electronic equipment (WEEE)			386.908		
Totals		2.241.300	67.371	386.908	180.253	139.31
Percentages		2,23%	74,33%	12,83%	5,98%	4,62%
Total		3.015.142				
Recovered versus disposed		95,38%			4,62%	

Table 34 – Output in 2006.
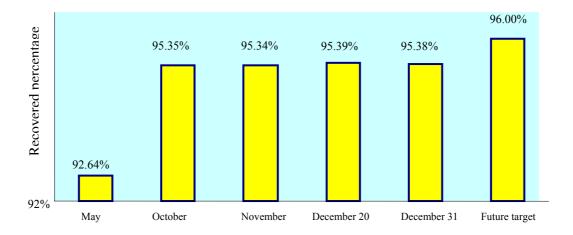
Figure 21 – Recovered percentages from May to December 2006.

6.4.1 The Inbound Process

Inbound transportation is outsourced to several transportation providers that collect disposed products from all over Italy and consolidate at the local hubs in order to guarantee full truck loading. Since transposition involves waste, it is crucial to have the

necessary waste disposal permission which is issued by the local competent authorities. Quantity and typology of the received material is known in advance. The customer payment is based on weight and product type and therefore these are crucial information.

The receiving is organised into several steps:

- receiving approval and weighting
- material identification
- update of book keeping registers
- update of documentation and movement to the unloading areas
- dispatching to the process areas or preliminary depot.

6.4.2 The Treatment Process

The process is differentiated according to the typology of the received goods.

The equipment which is received with order of demolition is first disassembled into valuable parts and waste (hazardous and non hazardous waste). The waste fraction is sent to authorized treatment plants. The parts are processed in order to extract valuable metals (distinguished in precious, ferrous and not ferrous metals). Equipment which is not covered by the obligation of destruction is also dismantled into parts and materials but parts which are valuable are remarketed or used for refurbishment. Whenever possible, it is preferable to remarket the entire machine; therefore refurbishment is performed in the case of:

- relatively new equipment in reasonable condition
- numerous of defective products appositely acquired from the market for refurbishment and remarketing.

The process is executed by specialised operators assigned to the working stations. Each working station is flexible and is adapted to process any kind of equipment. Processing capacity is measured in kg/hour. The average capacity is 80-100 kg/hour depending on the processed equipment. Capacity loading is generally performed on a monthly basis (sometimes over a 2-3 months period) but it is recalculated in the situation of incoming spot orders. For each processed lot, an environmental report is filled in with all relevant information regarding customer, lot weight and product type, recovered and disposed percentages detailed by materials and components (Table 35 exemplified a environmental report for a lot of DVD recorders. Sensitive information as customer name and values of the recovered materials has been removed).

Environmental Report - Environmental and economical evaluation				
LOT n…. DVD RECORDER		Client:		
		Product typology:	DVDR119	
Kg. 4.20		Date:		
Recovered				
Material description	Kg.	€/Kg.	Tot €	Recovered %
Iron	3.24			77.16%
Clean aluminium	0.58			13.80%
Dirty aluminium	0.05			1.19%
Cables				0.00%
Engines				0.00%
Transformer				0.00%
Cupper				0.00%
Golden modules				0.00%
Brass				0.00%
Palladium				0.00%
Magnesium				0.00%
Recovered plastic	0.15			3.57%
Connector A				0.00%
Connector B				0.00%
Connector C				0.00%
Board A				0.00%
Board B				0.00%
Board C	0.14			3.33%
Golden boards				0.00%
Recovered components				0.00%
Paper/paperboard				0.00%
Glass				0.00%
Wood				0.00%
Pallets				0.00%
Recovered waste from mixed packaging	0.04			0.95%
				0.00%
Total recovered kg.	4.20	Pay -off	€	100.00%
Disposal				
Material description	Kg.	€/Kg.	Tot €	Recovered %
Cathode tubes				0.00%
Batteries				0.00%
Cells				0.00%
LCDs				0.00%
Lamps				0.00%
Cartridge toners				0.00%
Toners				0.00%
Freon				0.00%
Printing ink				0.00%
Oil				0.00%
				0.00%
Total disposed kg.	0.00	Costs	€	0.00%
Total kg.	4.20			
Processing costs	€			

Table 35 – Example of the environmental report: treated lot of DVD recorders.

6.4.3 The Outbound Process

The output follows different paths according to its typology: waste is sent to disposal facilities specialised in the treatment of hazardous or not hazardous waste. Precious and valuable metals are acquired by refining and melting plants. Refurbished equipment, valuable harvested parts and components (hard disks, processors, audio and video boards) are acquired by brokers.

Figure 22 summarises inbound and outbound processes.
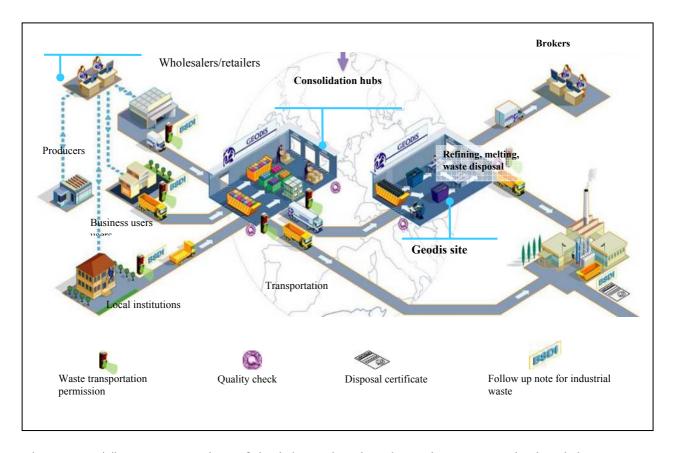
Figure 22 – The representation of the inbound and outbound process and related documents (for the kind concession of Geodis Italy).

This second flow presents grey areas since the product is received as waste and whenever possible remarketed as second hand product. If we take the point of view of the customer, it can be argued that the flow is not value driven since the customer pays for disposal also in the case the product retains a high residual value and it is refurbished and remarketed. The flow differs from the first because the customer is not a producer but business users of electrical and electronic equipment. Therefore they are not interested in refurbishing and remarketing the disposed products. Customers do not have the perception of the residual value of the products they dispose.

6.5 Conclusions

The chapter has presented two instances of a value driven recovery chain: the first case is customer and product specific, and the second is not customer specific and only partially product dependent. In both cases, the inbound, treatment and outbound processes are described into detail and values related to the total annual treated volumes are provided. The two flows are performed by the same third party logistics provider which offers different services in different contexts.

The following chapter (Chapter 7) analysis the two cases separately. The case analysis outlines limits, specific characteristics and insights of the two reverse chains while Chapter 8 combines the findings and answers the research questions.

Chapter 7. The Case Analysis

"At least once in a lifetime it is convenient
to put everything to discussion"
Descartes

7.1 Introduction

The objective of the chapter is to analyse the two cases described in Chapters 5 and 6.

This first part of the analysis (within-case analysis) aims at outlining considerations and insights derived from the case study investigation and it is preliminary to the cross case analysis presented in Chapter 8.

The first part of the chapter elaborates on the case analysis of the legislation driven reverse chain. The WEEE reverse chain analysis highlights the main limitations encountered at the institutional, configuration and operational levels. Since the legislation is not only the sole driver but also the main element that impacts the structure and the configuration of the chain, the analysis aims at pointing out to which extent the normative factor limits an efficient and effective implementation. Strategic choices as decentralization versus decentralization, specific assets investments, or collaborative partnerships are quite limited and constrained within the frame of the norms.

The second part of the chapter analyses the value driven reverse chain. In this case, attention is given to the impact of the strategic choices of outsourcing the recovery process, centralising or decentralising the recovery facilities, the role of the third party logistics provider in supplying reverse and recovery services.

7.2 The Case Analysis of the Legislation Driven Reverse Chain

The objective of the section it to present the insights derived from the analysis of the legislation driven reverse chain. The analysis considers the case of the implementation of the WEEE Directive in Denmark and how the Directive influences the recovery system.

§ 7.2.1 and 7.2.2 consider the major problems that limit an efficient and effective implementation and management of the WEEE reverse chain. While specific critical aspects of the WEEE Danish implementation are related to national implementation decisions and the strong contractual power of the recyclers (§ 7.2.1), several limitations are related to the WEEE Directive itself and are in common with the WEEE recovery systems implemented in the other EU Member States. The second part (§7.2.4) outlines the distinctive elements of the legislation driven reverse chain.

7.2.1 Major Limitations

One of the main principles of the WEEE Directive is promoting reuse as primary recovery option. Reuse limits landfill and incineration costs and reduces the extraction and consumption of virgin raw materials. It constitutes a complementary source to fulfil market demand. Therefore it represents the most effective recovery option. However, the way in which the Directive has been implemented in the Danish context has generated a recovery system which is not capable of an efficient sorting and in order to prevent cherry picking and it forces to convey the collected volumes to the recycling plants. Largely failing in promoting reuse and other recovery options as remanufacturing, repair and refurbishing, at the moment, mostly recycling is performed.

Other WEEE recovery systems, for example the one implemented in Finland, in order to avoid neglecting the reuse option, encompasses an intermediate phase subsequent to picking where the disposed products are sorted and the fraction that can be reused is separated (Lehtinen and Poikela, 2006).

Problems also arise in how to ensure that collective schemes get an equal share on the required efforts in terms of collected quantities from the waste municipal collection stations and from retailer's stores. Colleting from the retailing stores is advantageous due to higher volume homogeneity and higher collection points' concentration. The municipal collection stations are distributed all over the country and this forces the collective schemes to reach nearly every remote area of the Danish territory, islands included, with relevant transportation costs. On the contrary, retailers' stores are more concentrated, closed to the most inhabited areas, and easily accessible at lower transportation costs.

The system is also striving to assure that orphan products do not excessively load the remaining producers/importers. Orphan products refer to producers that are no longer on the market and therefore they do not contribute to the recovery process with the payment of the fee.

Finally, fragmentation of responsibilities and unclear coordination creates difficulties in identifying who should do what at which level. This introduces a higher level of complexity in the coordination mechanism and in the identification of the central decision maker.

The main critical factors of the Danish implementation at the institutional, configuration and operational levels are hereby presented.

7.2.1.1 Institutional Level

Even though the enforcement responsibility lies on the Danish Environmental Protection Agency, clear rules on how to proceed in case of free riders or companies who do not report reliable sales information have not been identified.

Besides, the current reporting system presents several weaknesses. First of all, many different actors are involved and they are not properly interfaced and connected. The reporting guidelines given by the WEEE-System do not provide indications for data reliability. The data collection is not consistent and each collective scheme has its own procedure. This creates extra work load to the WEEE-System in order to assemble the data for final reporting.

The Danish system planned the collection in 5 fractions but the reporting system has to comply with the 10 WEEE product categories. In fact, the Directive defines recovering and recycling/reuse targets by product category. To overcome this obstacle, the recyclers should periodically separate and process batches of products sorted by categories, however no indications on the frequency and sampling accuracy are given.

The WEEE-System, which is the organism that should supervise the configuration and operational tasks, has limited contractual power towards collective schemes and municipalities. This leads to inefficiencies, lack of coordination and difficulties in reaching agreements between the different stakeholders.

7.2.1.2 Configuration Level

At the configuration level major problems are encountered in relation to the allocation system for the B2C waste municipal collection points and incomplete procedures for the collection process.

The allocation of the collection points concerns the first phase of the recovery flow but it triggers all picking and transportation processes. It is performed annually by the

WEEE-System and the mechanism has been based on the manual assignment of the collection stations to the collective schemes according to their market share without any consideration on transportation routings or clustering criteria. A significant improvement could be carried out by applying an OR model that minimises the number of collective schemes assigned to the same collection station in order to minimise the number of actors each municipality should interface with (Table 36 shows briefly the mathematical formulation of the allocation model). The model assures that:

- all waste is collected;
- the market share of each collective scheme is respected;
- each fraction is assigned to only one collective scheme at each collection point.

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constants:

$i \in I / I = \{1 \ldots 78\}$ number of collection points

$j \in J / J = \{1 \ldots 5\}$ number of collective schemes

$k \in K / K = \{1 \ldots 5\}$ number of fractions

T   tolerance required in % of market share;

M   constant equal to number of fractions

S_{jk} kg of fraction k that collective scheme j must collect

$q_{i,k}$ kg of fraction k collected at the picking point i

variables:

X_{ij} is a binary variable, $X_{ij} = 1$ if picking point i is assigned to collective scheme j;

Y_{ijk} is a binary variable, $Y_{ijk} = 1$ if fraction k at collection point i is assigned to collective scheme j;

Objective function: $\min \left(\sum_i \sum_j X_{ij} \right)$

With the following constrains:

$$\sum_j Y_{ijk} = 1 \qquad\qquad \forall\, i, k; \quad i \in I,\ k \in K \qquad (1)$$

$$\begin{cases} \sum_i Y_{ijk} \cdot q_{i,k} \geq S_{jk} \cdot (1 - T) \qquad \forall\, j, k; \quad i \in I,\ k \in K \qquad (2) \\[2em] \sum_i Y_{ijk} \cdot q_{i,k} \leq S_{jk} \cdot (1 + T) \qquad \forall\, j, k \quad i \in I,\ k \in K \end{cases}$$

$$\sum_k Y_{ijk} \leq X_{ij} \cdot M \qquad\qquad \forall\, i, j; \quad i \in I,\ j \in J \qquad (3)$$

Table 36 – The mathematical formulation of the allocation model.

Since the containers are owned by the recyclers, the yearly re-allocation should not provoke a large re-placement of containers/cages, therefore the yearly allocation should consider the allocation performed in previous year.

The implementation and allocation procedures attempt to avoid convenient assignments that might privilege a collective scheme. For instance, a collective scheme allocated to the Copenhagen area would benefit of economies of scale by servicing the densest populated area with the most concentrated collection points. By supporting the idea that none of the collection scheme should be privileged in terms of routings and thereby assigning the collection points to the collective schemes on a random geographical basis, the system does not promote efficiencies in collection and transportation and it allows the proliferation of the transportation infrastructure. Therefore, even if the same settings are maintained, it would still be opportune to introduce clustering criteria in order to gain efficiency in transportation and reduce emissions. The WEEE-System could try to combine the two opposite requirements (fear competition and proliferation of the transportation routings) by promoting agreements between collective schemes once the allocation is performed. Some countries such as Ireland have solved the problem of the proliferation of the transportation infrastructure by simply dividing the country in some major regions comparable in terms of waste production and assigning each region to only one collective scheme.

In addition, in the allocation process the B2C WEEE returned to retailers and wholesalers should be included. This WEEE quota which in most of the cases is particularly valuable from a recycling point of view has been neglected in the assignment process and it has generated several problems in adjusting procedures and tasks while the system was performing.

In the B2B part of the WEEE implementation, poor guidelines have been given to report, register and monitor the contracts of business users that assume the producer responsibility in the buying process. Business customers are constantly complaining due to the increasing administration efforts and paper work required by the system: manufacturing and processing companies utilise a lot of electrical and electronic instruments for their production and operating sites; the number of different electronic and electrical appliances used by employees in the daily working life is quite considerable and the number and type of information that should be recorded for each buying contract is quite overwhelming.

7.2.1.3 Operational Level

At the operational level, inefficiencies are registered in the way recyclers are engaged in the picking process (picking frequency versus transportation capacity utilisation), where, and to which extent to consolidate in order to assure an adequate shipping load

efficiency and recycling capacity utilisation. The municipalities are allowed to decide the picking frequency, how to collect and sort the WEEE, and where to locate the collection stations. Neither the WEEE-System nor the collective schemes are engaged in the decision process and transporters have already informed the WEEE-System of municipalities that require a high service level (high picking frequency) without ensuring fully loaded containers. Since transporters and municipalities have opposite objectives (transporters have the interest to minimise the picking frequency, investments in the infrastructure and maximise the capacity utilisation, while municipalities require high picking frequency in order to minimise the space deployed to store containers and cages), the WEEE-System should have the necessary contractual power in order to intervene and promote consensus.

7.2.2 Limitations Caused by the Directive

The Directive imposes to report data related to collection, treatment, recycling and reuse according to 10 product categories. However, the criterion used in categorisation (10 product categories) does not reflect how products are collected and processed at the recycling plants. The origin oriented categorization of products used by the Directive was introduced around the middle of the 1990's. At that time, the primary concern was gaining control over toxic substances emissions, by promoting the Design for Recycling (DfR) and manual disassembly. Manual disassembly is not a reasonable treatment policy since it is too costly; treatment and recycling are mainly performed by shredding and quite basic forms of materials separation (air streams, magnetic fields). Therefore a more practical categorisation, that considered products materials content in terms of metals, glass and plastics and commonalities in terms of dimensions, occurred naturally. Indeed, most of the 27 EU Member States have decided to cluster the 10 product categories in fractions in order to reflect commonalities in the required treatment, size and materials content.

The WEEE Directive besides promoting DfR, also encourages all the Design for X techniques (design for disassembly, design for recycling, design for recovery) but it does not provide incentives to reward producers that adopt these methodologies in designing their products. None of the companies interviewed in this study perceived the Directive to have a notable impact in product design, apart from the need to mark the product with the WEEE symbol (labeling). And when it was asked if the Directive had impacted the supply chain to any extent for instance by introducing into the procurement process evaluation criteria for their suppliers, only one major producer (Nokia Corporation, see §7.2.3) had answered positively and had provided concrete indications of the use of the DfX techniques along with the Life Cycle Assessment (LCA) philosophy.

Furthermore, the Directive does not provide indications on how to link product design with the recycling process, i.e., how to transfer recycling knowledge into product design. The many phases and actors interposed between the OEMs and the recycling companies prevent producers in knowing how their products affect the recycling phases and due to collective collection and treatment, it results in time consuming, costly and difficult to access which products are more recyclable and on what basis.

Even if life cycle assessment and product life cycle management are mentioned in the Directive in order to evaluate the overall product environmental impact from design, to production, consumption, recycling and disposal, there are no indications on how these concepts could be included in product evaluation. Furthermore, the Directive completely neglects eco-efficiency evaluations, i.e., environmental gains over costs. By using eco-efficiency evaluations, it has been proven that if different recovery options equally contribute to the WEEE recycling targets, they do not contribute equally to the environmental results (Huisman et al., 2006). For instance the glass fraction recovered from the WEEE waste can be used to replace the sand in the building industry, as replacement of material in the ceramic industry or it can be used as a source of secondary material for new appliances. All these applications are counted by the Directive as effective reuse but they are not equivalent in terms of the environmental impact.

One major issue is related to the inner weakness of all European Directives that respect the principle of providing minimum requirements. Therefore, the large degree of freedom in the transposition process has caused 25 completely different national legislations (the two newly entered Member States cannot be considered at this point of time since they benefit from postponing provisions) with substantial delays (some countries do not have a transposition in place yet) both in legislative terms and infrastructure development. The lack of strict implementing guidelines has triggered some peculiar situations in different Member States. For instance, in France, the retailing industry and the municipalities have demanded disproportional compensations for the usage of collection space. 27 different transpositions are also causing useless extra administrative work load for multi-national producers and non EU importers that cannot adopt the same policy to comply with the Directive all over Europe. The recycling fee also differs from country to country as well as the rules for setting up the financial guarantee.

We finally notice that the Directive is deficient in promoting any performance measurement system other than the recovery and recycling/reuse targets (Table 37). And by not providing indications for the separate reporting of the reused and recycled fractions, reuse is in reality not promoted by the Directive itself.

Product categories	Recovery targets	Reuse/recycling targets
1. Large household appliances	80	75
2. Small household appliances	70	50
3. IT and telecommunications equipment	75	65
4. Consumer equipment	75	65
5. Lighting equipment	70	50
6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools)	70	50
7. Toys, leisure and sports equipment	70	50
8. Medical devices (with the exception of all implanted and infected products)	*	*
9. Monitoring and control instruments	70	50
10. Automatic dispensers	80	75

Table 37 – Recovery and reuse/recycling targets.

7.2.3 Implications for the Product Design: the Case of a Major Producer

No major changes were reported to have occurred due to the Directive in the design, manufacturing or procurement processes, apart from the additional WEEE labeling.

Only one interviewed producer, Nokia Corporation, has reported different initiatives assumed in order to reduce the environmental impact of its products: Life Cycle Analysis and improvements in the design phase in order to reduce the number of components and materials used in mobile phones manufacturing. Despite all the efforts, the producer reported two major obstacles.

Even thought in principle a product can be designed in order to respect or even exceed the recovery and recycling targets imposed by the Directive, there is no guarantee that the treatment process can achieve that targets. A lot depends from the recycling technology which is still quite primitive. Helena Castren, Senior Environmental Manager, CMO Sales & Marketing Europe, Nokia Corporation had to say: "We have done all the possible improvements already in the past 5 years in order to make our products recyclable. Now dismissed products should start to be collected so that recyclers start getting a stable products' flow and consider improving their own processes because we can design and produce the most recyclable product but if the proper recycling technology is not developed, all our efforts are in vain". Secondly, there is no compensation for the producers that invest in product improvements. And since the

collection is performed in bulk, there is not the possibility to differentiate and identify which brands should be rewarded.

7.2.4 The Main Elements of the Legislation Driven Reverse Chain

The previous sections have stressed the major limitations of the legislation driven reverse chain. We hereby provide the main distinctive elements.

7.2.4.1 Different Forms of Contracting

The producers interviewed within the case study were asked to answer questions related to their role as producers of electrical and electronic devices and also as users of electrical and electronic devices in order to gain knowledge of the B2C and the B2B flows.

The B2B waste stream was previously regulated and all producers had to take care of all kinds of produced waste, EEE waste included, by signing private contracts with recyclers and treatment plants certified by the EPA. For this stream, the only major difference is represented by the fact that contracts concerning purchased electrical and electronic equipment have to be reported and registered by the WEEE-System. Each of these contracts has to state the actor that assumes producer responsibility for collection, transportation and treatment at the moment of disposal. In most of the cases, the business user assumes producer responsibility.

In the B2C flow, the novelty is represented by the separate collection of EEE waste since Danish citizens have already had for many years, the possibility of disposing household appliances and consumer equipment via the ordinary municipal waste system. For this part of the EEE waste, there is no difference in the producers' behavior: all producers have decided to take part to a collective scheme in order to comply with the Directive producers' obligations (collective contracting). Only one Danish manufacturer has decided to implement an individual collection scheme (individual contracting). All the others have indicated that they do not have any economic benefit in implementing and managing the revere flow. In the B2C flow, products' disposal is geographically dispersed, characterised by low volumes and extremely aggregated in terms of brands, therefore individual collection does not make sense. The collective contracting and consortia agreements imply a low level of manufacturers' involvement, a very limited organizational commitment and no tangible investments on specific assets. Single producers have very limited control on how the collective scheme is managed and what happens to the products. Collective contracting is the most obvious answer to a legislation that does not reward brands according to their environmental commitment

and respond to the main legislative indication of enacting a collective responsibility for the historical waste.

7.2.4.2 Collective Schemes

Collective schemes can be generic or industry specific. Major players have formed industry specific schemes in order to afford common costs and exploit economies of scale in the treatment processes. Industry specific schemes can also be formed when companies have a direct interest in the reverse chain outcome, i.e., they directly purchase the raw materials resulting from the recycling process.

Other configurations see recyclers directly involved in creating and managing a collective scheme. The objective of the recycler is to gain a certain volume of the total waste to be treated. Since recycling facilities involve high set-up investment costs, entering the WEEE market by forming a collective scheme allows recyclers to assure a certain constant incoming waste volume to their plants. Recyclers already own the infrastructure for treatment as well as transportation, and therefore collective schemes supported by recyclers are usually able to offer a lower treatment price than those that have to rely completely on purchasing all services from collection to treatment. Since the collective schemes share the same logistics requirements for collection and transportation, and transportation costs mainly depend from the cost of the fuel, the competition is shifted towards the recycling prices. Therefore collective schemes that are backed by recycling companies might pursue a competitive advantage.

Furthermore, recyclers have the advantage of benefiting from in-depth knowledge of waste treatment processes, economies of scale (while treating WEEE waste they also treat other kinds of waste), existing procedures for cross country waste transportation and strong developed collaboration with recycling partners on a pan-European scale. Entries barriers are at the moment definitely advantaging recyclers. In Denmark, recyclers have strong contractual power. These actors have been present for a long time in the Scandinavia countries

7.2.4.3 Logistics Components

The entire flow (from collection to treatment) is guided by cost saving objectives since disposed products are treated as waste; therefore the time for processing is not relevant. The collection is decentralised in order to provide collection points to all citizens all over the country. Other forms of collection have been introduced in the most inhabited areas and in agreement with wholesalers/retailers (§5.3.3.1). After collection, disposed products are consolidated on a regional basis (Jutland, Funen, and Zealand) before to be transported to the recycling plants.

7.2.5 Legislation Driven Reverse Chain: Case Analysis Outlines

The legislation driven chain is affected by important limitations partly due to the Danish implementation system, partly related to the Directive.

In Denmark, the objective of promoting reusing has largely failed since there is not any intermediate phase for sorting and separating the fraction of products that could be reworked. Several inefficiencies are related to the way the systems has been designed and implemented. The mechanism of the allocation of the collecting points, in order to favour competition, does not consider the environmental impact of the proliferation of transposition systems and infrastructures. Contrasting stakeholders' objectives are not mitigated by a strong authority: while municipalities aim at minimising investments for dedicated collection areas forcing frequent picking, the transporters and recyclers aim at full truck loading and limited investments in the logistics infrastructure. The Directive, by promoting the extended producer responsibility, does not support producers' efforts to redesign products that facilitate recycling.

The system presents collective schemes differently configured: from pure administrative schemes to schemes that are backed by recyclers or logistics providers. Collective contracting is the compliance mechanism chosen by almost all the producers.

Collection is decentralised for obvious reasons (the necessity to capillary reach the consumers) but since cost saving is the main objective; consolidation is performed before shipping to the recycling plants.

7.3 The Case Analysis of the Value Driven Reverse Chain

This section presents the insights derived from the analysis of the value driven reverse chain. As described in Chapter 6, the value driven reverse chain has been investigated considering two different flows:

- Remanufacturing/refurbishment of the PC equipment. The remanufacturing is performed centrally in Mainz for leased products collected from 15 European countries.

- The pre-treatment of end-of-utilisation products in Busnago, Italy.

Both sites are owned by Geodis, a logistics service provider which offers forward and reverse logistics services.

7.3.1 The Analysis of the Remanufacturing Process

In the remanufacturing process, product conditions (entity of the damage/fault, cosmetics) directly influences the possibility of performing the refurbishment process. The first evaluation is applied at the receiving stage where the cosmetic conditions are evaluated; secondly, the entity of the damage is determined and reworking is based upon customer requirements.

In the contract with the customer, costs and time limits are specified in order to avoid performing any reworking that would be unprofitable.

The refurbishment time is important for two reasons:

 – the product loses value over time and therefore the time utilized to execute the refurbishment process is also a source of value loss.

 – Alphabeta has to close the leasing agreements with its customers within 12 days and the possibility of invoicing damages related to improper usage is then time limited.

IT consumer products are subjected to continuous technological improvements which determine fast obsolescence. In particular in the analysed case, PC equipment is subjected to a loss of value of 2% to 5% a month which drastically reduces the possibility of refurbishing products older than 5 years. Depending on the product group (notebooks, desktops, CRT monitors, LCD monitors, servers, printers) the limit is from 3 to 5 years. Furthermore, what emerges is that remanufacturing is product-customer dependant and centralised. The ARC in Mainz focuses on the refurbishment of PC equipment; work stations (in terms of repair equipment) and personnel (in terms of skills and capabilities) are product type dependent. The entire flow (from collection to order closed) is shaped to comply with customer requirements (time and repair quality constrains). The possibility to serve customers with different requirements is very limited because this would introduce inefficiencies to the dedicated system. The centralisation of activities has been decided for a variety of reasons:

 – Centralised operations allow to tightly controlling the repair quality standards. Local repair centres could introduce different routines that do not guarantee the same results.

 – Centralisation avoids duplication of resources (specialised repair equipment and personnel). The treated volumes do not justify multiple local investments. Local dedicated investments in specialised personnel and refurbishment equipment would be reasonable only in the case of local sizable incoming volumes.

 – Finally, centralisation allows Alphabeta to control the remarketing process.

It is said that in the remanufacturing process, product type and conditions are not known in advance since Alphabeta communicates to Geodis the list of the leasing contracts due to expire in the coming 30 days but not the content. However by sharing the content of the leasing contract, lead time could be further reduced. By knowing in advance the incoming product flow, the Asset Recovery Center could achieve improvements in planning refurbishment capacity loading (which is a critical factor in this process), prevent picks of work load, and schedule in advance the necessary incoming tests, all enhancements that could contribute to shorten the lead time.

Another critical point is that by avoiding any inspection when picking the product at the customer site, customers have the possibility to abuse the service and include goods which are not part of the leasing contract.

7.3.2 The Analysis of the Dismantling Process

The dismantling process is on the contrary, customer and product independent (within a certain product range) and with a tendency to decentralisation (the center only serves the Italian market).

The decentralisation is only partially determined by the strategic choice of minimising transportation costs. In fact, very strict regulations limit cross border waste transportation. Since the center acquires dismissed products as waste, expanding the business to other countries would require specific authorised permissions difficult to obtain: generally, permissions are not granted before 6-8 months after requirement and the routes have to be previously specified. Investments in time and resources for obtaining cross country waste transportation authorisation makes sense if the core business is recycling as in the case of the waste treatment companies. However, this is not the case of the center in Busnago which performs a dismantling process which is only preliminary to recycling. Nevertheless, economies of volumes are guaranteed by conveying country waste volumes to a single processing unit.

Product conditions are relatively important since customer payment covers the total dismantling and treatment costs. Obviously, since parts harvesting is part of the business, good product conditions facilitate extra profit generation by remarketing valuable parts and components and if possible, the entire refurbished machine.

Differently than the remanufacturing process, in dismantling the loss of value of the product over time is less critical. Since customers are invoiced for products treatment, processing costs are covered and margins are assured, therefore, there is less stringent pressure in the lead time: it is common that products station in the warehouse for a while before being conveyed to the working areas. For the same reason, capacity planning is not as critical as capacity planning for remanufacturing. Disadvantages are

registered instead in relation to competition since the service is not specific and the installed treatment capacity exceeds the collected volumes; therefore, competition on costs is so extreme that margins can be easily eroded.

In the dismantling process we see a major legal issue regarding contracts signed to treat products as waste while products are reconditioned whenever possible.

7.3.3 Value Driven Reverse Chain: Case Analysis Outlines

The two flows are different; while refurbishment is centralised, dependent on product typology (PCs equipment) and customer dedicated, pre-treatment is decentralised on a European level but centralised on a country level, partially product typology dependent and not customer specific.

The refurbishment unit is needs based oriented: all activities are tailored to comply with customer needs. It is the customer which imposes lead times, quality standards and remarketing policies. Reconditioning assets are customer dedicated while transportation assets are partly owned, and partly rented from local transportation companies.

The dismantling unit is variety based positioned providing the same service to a wide range of customers. Transportation assets are rented from local transportation companies while processing assets are owned.

Both processes aim at recovering value in the form of products (remanufacturing) or in the forms of materials, components, parts (in the dismantling process).

7.4 Conclusions

The chapter has presented the analysis of the two cases of this study: the legislation driven reverse chain and the value driven reverse chain.

The legalisation driven reverse chain presents several inefficiencies partly caused by the recovery network complexity, partly due to inappropriate decisions, lacking of coordination and clear assignment of responsibilities. Furthermore, the number of actors participating to the chain is also destined to increase: other collective schemes might enter the WEEE market in the coming years. The consequences for the collective schemes are higher competition and the necessity to differentiate the services provided to their members and for the chain, increasing complexity and coordination efforts.

The value driven reverse chain analysis has outlined that strategic choices impact the chain structure and configuration. In the value driven chain, decisions regarding remanufacturing locations, centralisation versus decentralisation, process specialisation are dictated by considerations of strategic nature since the objective is to generate a revenue stream rather than complying with norms at the minimum cost.

Insights and considerations will be further elaborated in the cross case analysis, the theme of the next chapter.

Chapter 8. The Cross Case Analysis

"The problem of man is complex:
he cannot understand the complicated
truths, neither remember the simple ones"
R. West

8.1 Introduction

While the case analysis presented in the previous chapter has outlined considerations and insights derived from the examination of each of the two case studies, the cross case analysis elaborates on the evidence emerging from the combined analysis.

The objective is to explain the findings in relation to the research questions.

The first part of the chapter answers the research questions: the evidence emerged from the cases is used to accept or reject the research propositions elaborated from the research questions. The second part presents and examines a general framework that can be applied in order to characterise different reverse supply chains. The framework is elaborated upon the basis of a central concept: the loss of product value over time.

We start by providing the definitions of the main concepts used in the cross case analysis.

8.2   Main Concepts

In the cross case analysis we make frequently use of thee main concepts: the product residual value, the recovery option and the using life cycle.

In order to answer to the research questions and conduct the cross case analysis we shortly define these concepts.

8.2.1 The Product Residual Value

In this context the product residual value is the value the disposed product retains.

Any product is supplied to the market for a certain price that is related to the value the customer gives to the product. The customer values the product depending on its usefulness, the service it provides, the level of need, aesthetic aspects, etc… The same criteria can be considered to determine the residual value of the disposed product. In addition, the main determinant factor to determine the residual value is to verify the existence of a secondary market which is willing to receive reworked products (repaired, refurbished, remanufactured) and at what price. The returned product can be in good conditions, still functioning but for instance obsolete from a technological point of view, replaced by a newer generation of products which provides the same function at a very low price, or more functions are incorporated in the same product. This can be easily exemplified with some cases.

Most of the returned mobile phones are not out of function. The reasons for purchasing a new mobile phone are usually related to additional functions incorporated in the same device (photo camera, audio-video recording and playing functionalities) or simply fashion related considerations. The substitution rate of mobile phones is around 1.5 years and tends to be lower within the youngest generations. These returned mobile phones do not have any residual value if we consider the European market but they can be sold in markets with high demand of simple-to-use and cheap mobile phones (for instance Africa). In this case, the price at which consumers are willing to purchase refurbished mobile phones becomes the main determinant factor to benchmark the two options of recovery value in the form of product or in the form of materials.

Portable computers are considered to be obsolete on average after 1-2 years of use. However after refurbishment they are usually remarketed as second hand products. Mobile phone network infrastructures are usually refurbished and remarketed since mobile operators utilise this second hand equipment for data storage.

From the examples it emerges that the residual value of the disposed product depends on:

- the existence of a market/demand of second used products
- the price the customer is willing to pay to purchase the reconditioned product.

If there is no demand of second used products or the price the customer is willing to pay does not exceed the costs for collection, reconditioning (repair, refurbishment or remanufacturing) and remarketing, the only way to claim value is to recycle components and/or materials.

8.2.2 The Recovery Options

Recovery options have been discussed in Chapter 1, §3.3.2. Recovery options are one of the key elements of the general framework presented in §8.8.1. Therefore, we briefly recapitulate them referring to Thierry et al., 1995 and we add the recovery operations (phases, §8.2.2.2) related to the recovery options of this study (reconditioning and recycling).

Five alternatives are given: repair, refurbishing, remanufacturing, cannibalization. From repair to recycling, the level of disassembly increases while the possibility to preserve intact the product structure decreases.

8.2.2.1 Alternatives

Repair is to return used products to "working order". It involves the fixing and/or replacement of broken parts and it usually requires only limited product disassembly and reassembly. Repair is usually performed at customers' location or at manufacturer controlled authorised repair centers. Examples are repair of copy machines at customer premises, repair of consumer goods as television, washing machines or dishwashers by authorised repair centers.

Refurbishing brings used products up to specified quality standards. Quality standards are less rigorous than those for new products. After disassembly, critical modules and components are inspected and if necessary, fixed or replaced. Approved modules are reassembled into refurbished products. Refurbishing can be combined with technology upgrading. Refurbishing improves quality and extends the products service life. For example, aircrafts, production lines or military systems are periodically refurbished.

Remanufacturing aims at reconfiguring the product in order to reach the same quality standards of a new product, therefore the product is completely disassembled and all modules and parts are extensively inspected. Worn-outs, outdated parts and modules are replaced with new ones. Repairable parts and modules are fixed and extensively tested. Approved parts are sub-assembled into modules and subsequently assembled into remanufactured products. Remanufacturing can be combined with technological upgrading. For example, car engines, starter motors and alternators can be remanufactured.

In cannibalisation, only a small proportion is reused and only in the form of parts. Cannibalization recovers a limited set of parts or components that can be used in repair, refurbishing and remanufacturing. The quality standard for cannibalised parts depends on the process in which they are reused (repair, refurbishing and remanufacturing). Parts for remanufacturing have to fulfill stricter quality standards than the ones reused in

repair or refurbishing. Examples are cannibalisation of integrated circuits or memory cards.

In repair, refurbishing, and remanufacturing, a large proportion of used products is reused and product structure is preserved. In cannibalisation, reusable parts are retained; in recycling, the identity and functionality of used products or some of their parts is completed lost.

Recycling aims at recovering value on a material level. Recycled materials can be reused in production of original parts if the quality of the materials is high or else in production of other parts. Recycling begins with disassembly and separations of parts according to distinct material categories. Different materials are then separated on the basis of different technologies.

In most cases, recycled raw material has to been refined in order to be redeployed into the original production flow. For instance, in the case of plastics, due to the many required technological properties and colours of the plastics utilised in all kinds of different products, the output of recycling cannot be reutilised for original purposes. In our study, we encountered one case of recycled raw material directly reutilised into production: the glass fraction derived from luminary recycling. Table 38 reassumes all recovery options.

	Level of disassembly	*Quality requirements*
Repair	Product level	Restore product to working order
Refurbishing	Module level	Inspect all critical modules and upgrade to specified quality level
Remanufacturing	Part level	Inspect all modules and parts and upgrade to "as new" quality
Cannibalisation	Selective retrieval of parts	Depend on process in which parts are reused
Recycling	Material level	High for production of original parts, less for other parts

Table 38 – Recovery options in relation to the level of disassembly and the quality requirements (adapted from Thierry et al., 1995).

8.2.2.2 Phases

Recovery options can be linked to specific recovery operations. The following set of activities is recurrent:

- Acquisition/collection
- Transportation
- Inspection/selection/separation/sorting

- Reprocessing/reconditioning
- Disposal

Whenever the product is reconditioned, distribution is needed in order to reintroduce the remanufactured/refurbished products into the original and/or secondary market. While acquisition and transportation are common phases, reprocessing and remarketing are distinctive of repair, refurbishment and remanufacturing (all together indicated with reconditioning). In case of reconditioning, the reverse supply chain presents the following key processes (Blackburn et al., 2004):

- Product acquisition which is to retrieve the used product from the user;
- Reverse logistics which is transporting the products to a facility for inspection and sorting;
- Inspection and disposition which is evaluating the condition of the returned product and make the most profitable decision for reconditioning:
- Repair/remanufacturing/refurbishment;
- Remarketing reconditioned products.

In case of recycling, the reverse chain presents the following key processes:

- Product acquisition;
- Reverse logistics;
- Treatment which is to extract and separate raw materials through different technologies (e.g., air streams and magnetic fields);
- Remarketing recycled raw materials;
- Landfill and incineration of not recyclable fractions.

8.2.3 The Using Life Cycle

In marketing theory, the classic product life cycle counts four stages (Figure 23): introduction, growth, maturity and decline.
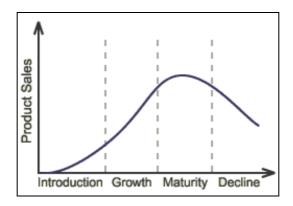
Figure 23 – The product life cycle curve.

At the introduction stage, market size and growth in sales is small. Products at this stage have to be monitored to ensure that they start to grow; otherwise the best option is to withdraw the product from the market. The growth stage is characterised by rapid growth in sales and profits. At this stage, it is convenient to invest in order to increase market share. The maturity stage is the most common stage for all markets. In this stage, the competition is most intense but it is also the time when most of the profit is earned by the market as a whole. In the decline stage, market share is shrinking, and the overall amount of profit that can be shared amongst the remaining competitors decreases.

While in marketing, the product life cycle is used in order to monitor the sales trends, in this study we refer to the product life cycle as the generic succession of stages a product undertakes from design to disposal (design, production, distribution, usage, support and ultimate disposal), which is the point of view adopted in Product Life Cycle Management (PLCM). In this context, we consider the using life cycle as that part of the product life cycle that competes to the usage of the product by the final user. Therefore the using life cycle refers to the period the product is on user's hands.

8.3 How the Cross Case Analysis is Structured

The proceeding sections answer the research questions and provide evidence to accept or reject the research propositions. Each of the three main research questions is first considered separately in detail (§8.4, §8.5, §8.6).

8.4 The First Research Question: The Reverse Supply Chain Configuration

The elaboration of design strategies for the reverse supply chain are only partially explored and rarely supported by qualitative evidence. And the "right" reverse supply chain structure can be determined if the design strategy has been defined and the objectives that the reverse chain has to achieve have been made explicit.

If the primary objective of the reverse chain is to recover products residual value, the chain design and configuration should guarantee short lead times and avoid any sort of delay since the product residual value is time sensitive and it erodes as time passes. On the contrary, if the primary goal of the reverse chain is to recycle EoL products and recovery value in the form of recycled raw materials, time is less relevant and cost efficiencies become predominant. If cost efficiencies can be achieved by economies of scale (large volumes), central consolidation points and hubs should be considered for the chain design.

Therefore, the first research question interrogates on the possibility of providing indications to guide the elaboration of the design strategy for reverse supply chains.

In Chapter 1, §1.2.1 we have assumed that there is a relation between the reverse supply chain structure and the recovery option. In particular, the primary objective should be to determine the reverse supply chain structure that better matches the recovery option and the recovery option is assumed to depend from the product residual value. The argument can be summarised as follows:

"The product residual value determines the recovery option that determines the reverse chain structure"

The argument has been made explicit in two research propositions (Chapter 1, §1.2.1).

- ▪ Proposition 1. The product residual value determines the recovery option (refurbishing, remanufacturing, and recycling): we can suppose that the higher the product residual value, the higher is the chance that the product can be refurbished/remanufactured/repaired and remarketed.

- ▪ Proposition 2. The recovery option determines the reverse chain structure, actors involved, configuration and relationships.

It follows that ultimately, the design strategy for the reverse supply chain depends on the product residual value.

8.4.1 The Relation Between the Product Residual Value and the Recovery Option

Proposition 1 assumes that if the disposed product retains a high residual value, it is reasonable to consider recovery options such as repair, refurbishment, remanufacturing, with subsequent trading on secondary markets. We call these recovery options as first class and preferable options since they recover value in the form of reusable products.

If the product has a low residual value, recovery options such as cannibalisation and recycling should be considered instead. We call these recovery options second class options since the product structure is lost, the value is recovered in the form of materials, components, energy generation through incineration and the fractions that cannot be recycled are disposed by landfill.

The evidence emerged from both cases supports the argument of proposition 1 (Table 39):

- – The legislation driven reverse chain processes disposed products with low residual value and products are conveyed to recycling. Since the chain treats products with low residual value, the focus is on recycling and energy recovery in the form of incineration.

- – The value driven reverse chain processes disposed products with high residual value and products are remarketed after reconditioning. The chain which deals

with disposed products with high residual value concentrates on refurbishment and remanufacturing.

	Recovery option
Legislation driven reverse chain	Recycling and energy recovery
Value driven reverse chain	Refurbishment and remanufacturing

Table 39 – Reverse chain and recovery option.

8.4.1.1 Low Product Residual Value and Recycling as Recovery Option

The legislation driven reverse chain processes returned products with low residual value and products are conveyed to recycling.

The fact that the legislation driven reverse chain deals with low product residual value is immediately explained by considering the typology of returned products. The flow generates mainly historical waste, products that have been on use for long periods and are dismissed by consumers or business users generally when broken and repairing the damage costs more than purchasing a new product. Returned products are in general obsolete and surpassed by products with enhanced functionalities and newer technology.

Secondly, the flow is characterised by bulk and extremely aggregated collection process which prevents the sorting and separation of disposed products that might retain a certain value (even if modest) and disposed products with low residual value. Collection is performed in five fractions and each of the fraction aggregates very different products. For instance fraction 4 groups 5 different WEEE categories (2, 6, 7, 8 and 9) include IT equipment such as mainframes and portable computers, electrical and electronic tools such as drilling and sewing machines, toys, medical devices and monitoring instruments such as thermostats or smoke detectors.

Collective collection does not promote sorting and in the case some kind of sorting is possible, the option to recover the product residual value is not even considered. This is the case of the wholesale and retail chains that have the obligation to take back products on a one-to-one basis and also receive commercial returns. Commercial returns are in general very valuable products but most of the major retailing stores prefer to categorize them as waste instead of performing testing, eventual repair, repacking and place the product back on shelf. This is mainly due to warranty issues: the returned product cannot be sold with the same warranty conditions and eventually retailers have contracts with their suppliers in order to obtain rebates, discounts or refund in case of defective products. The case of a major Scandinavian wholesaler chain of electrical and electronic appliances exemplifies clearly this policy: ElGiganten issues all kinds of returns as waste.

Even thought a small share of the returned products might hold a certain residual value, the legislation does not support the reuse of the product as such, and does not reward producers that choose to separately collect their own products. Furthermore, in the case of the B2B flow, most of the business users require the physical destruction of the dismissed product in order to protect confidential information.

Since the majority of the dismissed products have a low if not null residual value, all returned products are conveyed to recycling. This supports the argument that low residual value calls for second class recovery options, such as recycling and incineration.

8.4.1.2 High Product Residual Value and Reconditioning Recovery Option

The value driven reverse chain processes disposed products with high residual value and products are remarketed after reconditioning. First class reconditioning options (repair, refurbishment, remanufacturing) are carried out when the product residual value is high.

The two instances of the value driven reverse chain, the refurbishment and remanufacturing process (the case of Geodis Germany) as well as the dismantling process (the case of Geodis Italy) both aims at recovering value in the form of products whenever the residual value is high enough to justify transportation, reconditioning and remarketing.

In the first flow (Geodis Germany), the information that the product residual value is high is well known in advance since dismissed products are leased products, with a known using cycle, technology and with a reasonable margin of certainty, also the returning conditions are known. This is the reason why the producer Alphabeta has decided to support this profit generation opportunity with reconditioning and remarketing, maintaining the property of the dismissed products throughout the whole process.

In the second flow, Geodis has invested in facilities to offer dismantling and preliminary treatment. In this case it is not known in advance if the product residual value is high and this is the reason why customers pay for the service, and reconditioning is only performed whenever the received product has high residual value. Once more, reconditioning options of first class are tied to high product residual value.

8.4.2 The Relation Between the Recovery Option and the Reverse Chain Design

Proposition 2 assumes that once the most convenient recovery option is determined by assessing the product residual value, the recovery option affects the reverse chain structure, actors involved, configuration and relationships.

Clearly the recovery option determines the number and the characteristics of the phases and to some extent the number and type of actors involved. Less evident is that the recovery option is also critical to guiding crucial decisions that impact the overall reverse chain configuration such as centralisation versus decentralisation, outsourcing, lead time, contractual agreements, etc...

In particular, recovery options such as repair, remanufacturing and refurbishment are to different levels time dependent since the product residual value erodes as time passes. Therefore the reverse chain should to be designed in order to minimise delays and balance short lead times with costs efficiencies. A way to achieve short lead times and minimise delays is to decentralise the sorting and testing phases in order to rapidly direct the returned products to the most advantageous recovery alternative. Such a decision, decentralising sorting and testing, would already delimit, for a large part, any further configuration choice.

In the case of cannibalisation and recycling as recovery options, that are not time sensitive, the reverse supply chain should be structured in order to maximise costs efficiencies. In this case, centralisation both in processing and transportation would result a most obvious decision in order to provide economies of scale.

Both cases support the argument of proposition 2:

- For the legislation driven reverse chain, recycling is the only recovery option. Recycling, aiming at cost efficiencies, calls for centralisation of the transportation and treatment process. Recycling imposes the presence of some kind of actors as recycling and treatment companies as well as institutional actors that should assure the correct handling of the waste and provide norms. Finally, since waste recycling is regulated by norms, the relationships between the actors are very much determined by specific contractual agreements.

- For the value driven reverse chain reconditioning is the recovery option. As specified before, reconditioning comprehends of repair, refurbishment, and remanufacturing. Reconditioning is time sensitive and reducing delays and lead time imposes certain choices that affect the chain structure. Reconditioning imposes the presence of specialised actors with specific assets (equipment for testing and repair, trained personnel). The relations between the actors involved are not regulated by legislations and are more based on agreed contracts, trust, commitment, and mutual dependence.

8.4.2.1 Recycling as Recovery Option and Reverse Chain Design

Recycling affects the chain design and the chain structure in the two main following ways:

- By aiming at cost efficiencies, recycling calls for centralisation of the transportation and treatment process.
- Secondly, recycling forces the presence of actors such as recycling and treatment companies, institutional and governmental actors, logistics providers that own specific hauling infrastructure for waste transportation.

In the legislation driven reverse chain, characterised by recycling as the sole recovery option, this is certainly proven. Collection sites are geographically dispersed in order to facilitate product disposal and are imposed by the WEEE authority but as soon as picking is performed, the waste is consolidated before being transported to the treatment plants (Figure 24). And the picking process itself calls for full truck loading criteria and full container capacity utilisation. Full utilisation of the treatment capacity is also relevant to gain economies of scale.

Consolidation points determine a centralised chain structure. The centralised structure minimises processing and transportation costs at the expenses of long lead time that is irrelevant in the case of waste treatment.
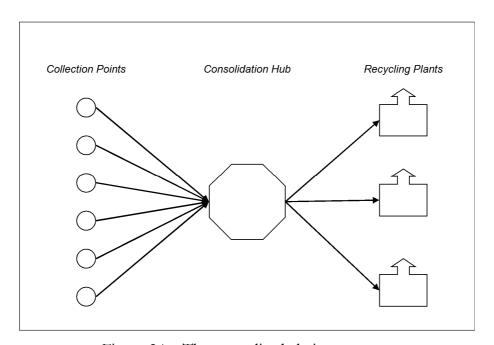
Figure 24 – The centralised chain structure.

Recycling forces the presence of actors such as recycling and treatment companies, institutional actors, specified logistics companies that own specific trucks for waste transportation.

In the most common situation, collective contracting, actors interface with a low frequency. Producers sign into a collective scheme once a year. The collective schemes

report the data to the WEEE authority once a year and they interface slightly more frequently with the municipal authorities, logistics service providers and treatment companies. Since waste recycling is regulated by norms, relationships are very much determined by specific contractual agreements that specify conditions for picking frequency, equipment renting, payments, reporting of recycled percentages, and information on the treatment process. Contracts are usually renegotiated once a year and they are only based on price criteria. Most of the activities are subjected to precise procedures.

8.4.2.2 Reconditioning as Recovery Option and Chain Design

For the value driven reverse chain, reconditioning is the recovery option. Since reconditioning is time sensitive and reducing delays and the lead time is crucial, the decentralisation strategy would be the preferred one.

The decentralisation of the testing and repair phases accompanied by a preponement strategy is invoked in the literature to reduce lead time and delays. In Blackburn et al., 2004 the decentralisation of sorting and testing as well as preponement are indicated as a way to maximise asset recovery by fast tracking returns to their ultimate disposition, minimising the costs for delay.

In this context, preponement means early differentiation of the disposed product, i.e., early product diagnosis. The concept of preponement would be the opposite of postponement product differentiation applied in the forward supply chain to delay the addition of features until the product is closer to the customer to avoid the costs of carrying separate inventories of all varieties of final products (Blackburn et al., 2004). Early decentralised diagnosis would reduce the lead time by avoiding unnecessary transportation and queuing of the fraction of products that could be directly restocked or scraped. By early diagnosis, products are directed as soon as possible to the most proper recovery option (Figure 25).

Delayed Product Differentiation

Field

N = New Stock

Early Product Differentiation

N = New Stock
R = Refurbishable Unit
C = Salvagable Unit
S = Scrap
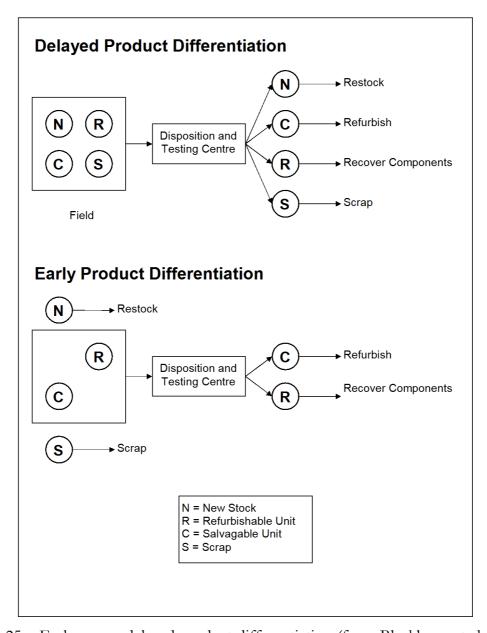
Figure 25 – Early versus delayed product differentiation (from Blackburn et al., 2004).

This would guarantee that the product residual value of the products that are candidates to reconditioning, and products that can be directly restocked is not eroded by unnecessary long waiting and queuing times. And by early directing the scrap and restock part of the flow to proper disposition, the processing of the remaining part (products candidate to reconditioning) would speed up: separating the extremes of product conditions (new and scrap) from the flow, the main flow of returned products requiring further evaluation is reduced.

In the same article we find that all these arguments can be soon invalidated in the case of:

- Missing technical feasibility of the solution, which means to be able to determine the condition of the returned product in field quickly and inexpensively;
- Missing supply chain partners collaboration. Early decentralised product differentiation relies on supply chain partners' availability, typically the ones closer to the customer, to carry out the necessary activities at the point of return.

At least one of the two adversary arguments to decentralisation identified by Blackburn el al., 2004 is verified in the value driven reverse chain analysed in this study. Both the instances of the value driven reverse chain do not support the argument of decentralisation. The first flow is clearly centralised and many reasons support the decision of centralising both testing and reconditioning. The second leads towards centralisation but motivations related to the nature of the transported products promote a centralised national structure, which results to be decentralized if we consider the supranational context (European level).

The first case, the value driven reverse chain operated by Geodis for Alphabeta is characterised by centralised testing and reconditioning. We already pointed out in the case analysis (Chapter 1, §7.3.1) all the reasons for centralisation. Centralised operations allow tight control of repair quality standards. Local repair centres could introduce different routines which do not guarantee the same results. Quality standards of reconditioned products are particularly critical for Alphabeta and centralised operations reduce the risk of variances. Centralisation avoids multiple investments on specialised resources. The treated volumes do not justify multiple local investments. Local dedicated investments on specialised personnel and refurbishment equipment would be reasonable only in the case of sizable incoming volumes. The refurbishment center of Geodis Germany has the capacity to serve 15 European countries. Remaining volumes are directly treated by Alphabeta producer in Montpellier, France. Finally, centralisation allows Alphabeta to control the remarketing process, the network of brokers that acquire the reconditioned products and resell them in secondary markets.

The second case, the value driven reverse chain operated by Geodis Italy also presents centralised testing and dismantling. However, centralisation is on a national basis while Geodis is an international logistics service provider. During the interview with the managing director of the Geodis Italian Reverse Logistics Center, it emerged that the decision to serve only national customers was not dictated by considerations related to decentralisation and short lead time. Instead exceeding processing capacity would invite for expanding the market by offering the same service to international customers and outside the Italian territory. However, since the center acquires disposed products as waste, complications can arise in case of cross border transportation. In order to avoid difficulties related to the approval of cross border transportation authorisations, Geodis has decided to maintain a national approach. The national approach is also determined

by a clear policy decided by Geodis which tries to avoid internal competition between different Reverse Logistics Centers operating in different countries.

In both cases, even thought the sorting and reconditioning activities are centralised, the lead time is kept under control with an adequate reverse logistics policy. Short lead time, which is predominantly important in the first case, is guaranteed by fast reserve logistics which penalises full transportation capacity utilisation in order to comply with the 14 days for order closed contracted with the customer. In this case the necessary trade-off between speed and costs efficiencies occurs. Despite this, since the reverse chain deals with which lose value at the speed of 2-5% a month, the trade-off is towards speed.

Reconditioning imposes the presence of specialised actors with specific assets (equipment for testing and repair, trained and skilled personnel). The relations between the actors involved are not regulated as in the legislation driven reverse chain by norms but are more based on trust, commitment, and mutual dependence. This is especially verified in the first case, the Recovery Assets Center (ARC) of Geodis in Germany which is fully dedicated to serve one single customer. Customer and service provider are very much tied up and they elaborate periodically together on strategies to reduce the lead time, improve the service, and enhance the quality standards of the reconditioned products. The ARC has invested in specific customers' dedicated assets. This presumes that the ARC safeguards its investments with long term contracts; however, the customer also relies on the long term established relationship.

8.4.3 The Efficient Versus Responsive Reverse Supply Chain

We have said at the beginning of this section that if the primary objective of the reverse chain is to recover product residual value, the chain design and configuration should guarantee short lead time; on the contrary, if the primary goal is to recycle EoL products and recover value in the form of recycled raw materials, time is less relevant and costs efficiencies become predominant. This could be reinterpreted in terms of a responsive reverse supply chain in the first case and an efficient reverse supply chain in the second case.

In 1997, Fisher in his paper "What is the right supply chain for your product?" proposed to analysis the demand pattern in order to determine the supply chain design. He distinguished between functional products with stable demand and long life cycles and innovative products with variable demand and short life cycle. He then proposed two different fundamental supply chain structures:

- – the efficient supply chain designed to deliver products at low costs
- – the responsive supply chain designed for speed response

concluding that the appropriate matching is the efficient supply chain for functional products and the responsive supply chain for innovative products (Table 40).

	Functional products	*Innovative products*
Efficient supply chain	match	mismatch
Responsive supply chain	mismatch	match

Table 40 – The matching supply chain with products (from Fisher, 1997).

Is it possible to use an equivalent product characterisation (functional, innovative) for the reverse supply chain and by then deriving appropriate considerations regarding the design strategy?

The relevance of Fisher's model for reverse supply chains is clearly seen by recasting it in terms of product residual value. The product residual value can be considered the only independent variable in the reverse logistics arena. It is itself determined by many different factors as returned product status, intensity of usage, as well as the existence of a secondary market but all these factors are exogenous, external to the reserve supply chain. Therefore, the product residual value is a given condition for the reverse chain and from the evaluation of the product residual value derives the choice of the most proper recovery option. To complete the parallelism with Fisher's model, we can say that products defined as innovative in Fisher's taxonomy correspond to disposed products with high residual value while functional products correspond to disposed products with low residual value. Therefore, continuing the parallelism, responsive reverse supply chains should be designed for disposed products with high residual value while the efficient reverse supply chain correspond to disposed products with low residual value (Table 41).

	High residual value products	*Low residual value products*
Efficient reverse supply chain	mismatch	match
Responsive reverse supply chain	match	mismatch

Table 41 – The matching reverse supply chain with the product residual value.

In order to characterise the responsive and efficient reverse supply chain, Fisher applies the following dimensions: the chain primary focus, the manufacturing focus, the inventory strategy, the lead time focus, the approach to choosing suppliers and the product design strategy (Table 42).

In the case of reverse supply chain in order to determine if the reverse chain should be efficient of responsive we consider relevant (Table 43):

1. the primary purpose
2. the manufacturing focus that in reverse chain can be seen in terms of recovery focus
3. the lead time focus

The primary focus

The evidence emerged from the analysis has revealed that the legislation driven reverse chain primarily aims at recycling the incoming volumes gaining costs efficiencies and respecting recovery targets while the value driven reverse chain primarily aims at reducing time delays and shortening the lead time.

The recovery focus

Considering the recovery process focus, the legislation driven reverse chain attempts at maintaining a high utilization level of the deployed infrastructures (transportation facilities and treatment facilities) while the value driven reverse chain needs to balance high utilisation rates with short lead time.

The lead time focus

The legislation driven reverse chain is not time sensitive. Returned products have low or no residual value therefore time of recovery is irrelevant while lead time focus is predominant in the value driven reverse chain.

	Efficient chain	Responsive chain
The chain primary focus	supply a predictable demand	respond to unpredictable demand
The manufacturing focus	maintain a high utilisation rate	deploy buffer capacity
The inventory strategy	minimise inventory	deploy buffer stocks
The lead time focus	shorten lead time as long as it does not increase cost	invest aggressively in reducing lead time
The approach to choosing suppliers	select suppliers for cost or for speed	select suppliers flexibility
The product design strategy	maximise performance and minimise cost	use modular design and postpone product differentiation

Table 42 – Physically efficient versus market responsive supply chains (adapted from Fisher, 1997).

	Efficient reverse supply chain - the legislation driven reverse chain	Responsive reverse supply chain – the value driven reverse chain
Primary focus	Recycle efficiently incoming volumes and maximise recovery targets	Recapture most of the product residual value
Recovery process focus	Maintain high average utilisation rate of the recovery infrastructures	Compromise between high average utilisation rate of the recovery infrastructures and the requirement for short lead times
Lead time focus	Irrelevant or shorten lead times as long as it does not increase costs	Investments to reduce the lead time

Table 43 – Efficient versus responsive reverse supply chains.

8.4.4 The First Research Question - The Reverse Chain Configuration: Conclusions

The first research question interrogates on the possibility of providing indications to guide the elaboration of the design strategy for reverse supply chains. It has been hypothesised that the reserve chain design depends from the recovery option with ultimately depends from the product residual value. Proposition 1 has postulated the dependency of the recovery option from the product residual value and proposition 2 the relation between the recovery option and chain design strategy. From the cross case analysis it emerged that both propositions are supported by the case evidence.

The legislation driven reverse chain, which deals with disposed products with low or null residual value has recycling as recovery option. Since efficiency is imperative for recycling, the chain structure is arranged in order to gain cost efficiencies. Central consolidation hubs are utilised in order to centrally collect all the waste delivered at the municipal collection stations distributed all over the country. By consolidating, the chain obtains economies of scale in transportation and treatment. The actors participating in the chain are recycling companies, governmental and institutional organisms, specialised logistics providers, and producers' associations.

The value driven reverse chain, which deals with disposed products with high residual value, has reconditioning as recovery option. Since reconditioning is time sensitive and the product residual value decreases as time passes, it is crucial to reduce the lead time and eliminate delays. The first instance (I.1) of the value driven reserve case, the chain operated by Geodis Germany for the producer Alphabeta is extremely time dependent: 14 days is the total available lead time from collection to order closed. Chain responsiveness is reached to the detriment of costs efficiencies in transportation. The trade-off between cost saving and responsiveness is in favour of time reduction.

The second flow (I.2) considered in the value driven reverse chain case is less time dependent since it acquires a mix of products with different residual value.

In both cases (I.1 and I.2), even thought short lead times would call for decentralisation, the flows present a centralised chain structure. The costs for establishing local testing and reconditioning facilities are not justified by the modest local volumes.

The actors participating in the chain are logistics service providers, producers and business users. Table 44 summaries the evidence emerged from the cross case analysis for the first research question.

- LDRC stands for legislation driven reverse chain.
- VDRC-I.1 stands for value driven reserve chain, instance 1.
- VDRC-I.2 stands for case study 2, value driven reserve chain, instance 2.

These are the acronyms that will be henceforth used to indicate the legislation and value driven reverse chain instances.

	Product residual value	*Recovery option*	*Strategic design purpose*	*Chain structure*	*Actors*
LDRC	Low or null	Recycling	Reduce costs - efficient chain	Centralised	Recycling companies Governmental organisms Specialised logistics providers Producers associations
VDRC-I.1	High	Remanufacturing Refurbishing	Reduce time, trade off costs time efficiencies, responsive chain	Centralised	Logistics provider Producer
VDRC-I.2	Mix of different products with different residual value – from high to low	Disassembly Remanufacturing Refurbishing	Depending from the incoming products - could be both costs and time efficiencies	Centralised	Logistics provider Producers Business users

Table 44 – The first research question: case studies analysis results.

8.5 The Second Research Question: Integrating the Reverse and Forward Chain

The second research question examines if the integration between the forward and reverse chain is a desirable objective and if it is common to encounter this kind of arrangement. The motivation to investigate the integration issue originates from the

examination of recent supply chain management literature that poses a lot of attention on the integration element. Integration is considered the primary component the supply chain has in order to become and stay competitive. In literature, integration is seen in terms of collaboration and cooperation. Integration can be achieved with many different initiatives as collaborative product development, information sharing, concerted inventory management, proactive instead of reactive response to market fluctuations, etc...

The integration between the forward and reverse chain could be advantageous for improving the competing ability of the total chain, developing synergies (economies of scale, economies of scope), or improving the performances of the recovery process by utilising in the reverse chain the product knowledge embedded in the forward chain.

However, even thought integration seams preferable, it not so common to encounter forward chains that also embrace the reverse flow. In 2007, Herold examined the level of involvement of multinational manufacturers in EoL product management in different regions of the world, and what company specific factors impact the level of involvement. In most of the cases, it emerged that the original producer is not even involved in controlling the reverse chain. The only exception is represented by Japanese producers which are heavily involved in EoL management since national legislation forces them to invest in recycling facilities. The study focuses on EoL products management policies, meaning products with a very low residual value. However, even thought management policies for EoU or commercial returns are considered (returned products with high residual value), what appears more frequently are two distinct flows with different actors and different strategic objectives. This is also the evidence emerging from this study. Both case studies support the argument of none or very limited integration. Therefore it is relevant to disclose why the two chains do not naturally converge towards integration: what are the reasons the producers have pointed out to explain the absent or low level of involvement in managing the returned products flow?

8.5.1 How to "Measure" the Level of Integration

Prior to addressing the reasons for low or no integration, in order to evaluate if the reverse and forward flows are or are not integrated, it is necessary to establish an evaluation criterion. We consider two metrics:

- To which extent reverse activities are performed in-house or are outsourced.
- The level of involvement of the producer in managing returned products.

The first metric considers to which extent reverse activities are or are not outsourced. Theoretically, there could be several situations: producers that outsource the reverse logistics processes and perform internally the testing and reconditioning phases, or the

opposite, i.e., producers that perform reverse logistics and outsource reconditioning, companies that totally manage and perform the reverse activities or outsource them completely.

In proposition 4 (Chapter 1, §1.2.2) we have assumed that:

- Proposition 4. The probability that reverse activities are not outsourced is higher if the manufacturer is directly involved in the reverse chain.

The level of outsourced activities is quantified with:

- A – High level, most or the total of the reverse activities are performed in-house.
- B – Medium, some of the reverse activities are performed in-house.
- C – Low, only marginal activities performed in-house.
- D – None, activities are totally outsourced.

In relation to the level of outsourcing, we refer only to product processing related reverse activities i.e., monitoring the process or dealing with information related to the process are not considered product processing activities.

The second metric, the level of involvement of the producers in managing the products return flow can be expressed by the typology of the developed capabilities (Herold, 2007) and thus the amount of internal dedicated resources both in terms of personnel and equipment.

Companies can limit themselves to the development of internal capabilities to manage contracts. This is the case of companies that manage the products return flow with individual or collective contracts: their need is to develop the capability to select the service providers. Vice versa, companies that take back their own products and recover something from them need to develop capabilities to manage the process and ways to get the products back. When companies take back their own products and perform some or all of the return management process, there is the need to allocate internal resources to the tasks. The amount of internal dedicated resources, in terms of personnel and equipment, is also an indication of the level of involvement of the producer in recovery management.

Herold, 2007 distinguishes five levels of involvement, from none to vertical integration: none, collective contracting, individual contracting, individual recovery and vertical integration.

No involvement in any of the product recovery management processes. The existence of a return flow is completely ignored.

Collective contracting is the lowest level of involvement characterised by very limited organisational capabilities and the presence of take-back schemes and consortia. This is the case of producers participating in industry wide take-back initiatives and compliance schemes. The amount of internal dedicated resources is limited to personnel that monitor the contracts and partially the data related to the flow. The dedicated personnel frequently belong to the Regulatory Affairs Department (or equivalent) of the company.

Individual contracting is also characterised by a low level of organisational capabilities and no tangible assets. The only difference in respect to collective contracting is that the producer manages the contract independently with selected partners.

Individual recovery indicates a high level of involvement and superior organisational capabilities since the company treats to some extent its own products and take control over the return flow. In this case, dedicated specific resources (personnel and equipment) are deployed for recovery.

Vertical integration denotes the case of a producer vertically integrated into returns management, investing in treatment facilities. The amount of internal dedicated resources in terms of personnel and equipment is very high. Disinvesting in recovery would mean disinvesting parts of the company.

In Chapter 1, §1.2.2 we have assumed that:

- ▪ Proposition 3. The higher is the level of involvement of the original manufacturer in the reserve chain, the higher is the probability that the forward and the reverse chain converge towards integration.

8.5.2 Integration: Results from the Cross Case Analysis

By applying the two metrics to the two case studies, it clearly emerges that the forward and reverse chains are not integrated.

Mainly, the totality of the activities related to the reverse chain is outsourced (level D) but with some differences.

In the first instance of the value driven reverse chain (VDRC-I.1), the producer Alphabeta takes over the remarketing phase (level C) and one producer of the legalisation driven reverse chain (LDRC) performs parts of the recovery activities. The producer called Zitech which sells stationary and portable PCs and all related devices has implemented its own individual compliance scheme and it performs some of the phases of the recovery process (the collection, dismantling and parts harvesting) in-house. The remaining (recycling of scrap) is outsourced (level B).

In relation to the level of involvement, in both instances of the value driven reverse chain (VDRC-I1 and VDRC-I.2), the producer manages the reverse chain with individual contracting (level 3).

In VDRC-I1 even though the physical process is performed by the Geodis Asset Recovery Center (ARC), the producer Alphabeta has a quite detailed overview and control of the overall process from collection to order closed. The producer has dedicated in-house personnel that follow up on contractual agreements with Geodis. Regular meetings are held with the Geodis ARC managing director in order to discuss possible process improvements mainly related to the possibility of reducing the lead time and improve quality standards.

In VDRC-I.2, the Geodis Recovery Center in Italy offers the reconditioning or disposal service on the basis of individual contracts. Often in this case, customers are business users (B2B sector). In terms of the WEEE-Directive, they could be defined as producers in the case they take over the responsibility for product disposition. However the Directive is not enforced in Italy. The level of involvement is limited to the contractual process which usually takes place once a year. Rarely are spot contracts signed. The producer is not interested in monitoring the reverse flow or receiving final reporting information. The only concern is related to legislation compliance: in the contract, the Geodis Recovery Center has to assure that the process is performed according the general norms related to waste management.

In the legislation driven reverse chain (LDRC) the level of involvement is limited to collective contracting (level 2). The amount of internal dedicated resources is limited to personnel monitoring the collective contractual, receiving the final recycling figures. In LDRC, the producers participate in collective schemes. Since producers are legally responsible in terms of possible violations of the legislation, they have a certain interest in receiving annual reporting data and receive assurance from the collective schemes that all processes (in particular treatment) are performed in compliance with the WEEE-Directive and local legislation. Producers also have to provide the collective scheme with a yearly account on sales forecasts.

We did not find any of the interviewed producers that ignored the existence of a recovery flow (level 1). The results of the analysis in respect to the integration issue are summarised on Table 45.

	Outsourced or in-house performed activities	Level of involvement of the producer
LDRC	Level D. Only one producer reaches level B.	Level 2
VDRC-I.1	Level C	Level 3
VDRC-I.2	Level D	Level 3

Table 45 - Results from the cross case analysis for the integration issue.

Legend of the figure

Level A – Most or the total of the reverse activities performed in-house.	Level 1 – No involvement
	Level 2 – Collective contracting
Level B – Some of the reverse activities performed in-house.	Level 3 – Individual contracting
Level C – Only marginal activities performed in-house.	Level 4 – Individual recovery
Level D – None.	Level 5 – Vertical integration

8.5.3 The Reasons for the Low Level of Integration Between the Forward and Reverse Chain

We have identified that both in terms of the extension of reverse activities performed in-house and the level of involvement of the producer, the level of integration is very limited, but it still remains to discuss what are the reasons the producers have pointed out in order to explain and motivate the low level of integration between the forward and reverse supply chain, and therefore to identify why the two chains do not converge towards integration.

During the interviews conducted with the producers, along with all other questions, the following one was always posed: "why are you not involved in the reverse chain?" The reasons are hereby reported according to the responding frequency starting from the reason that has been indicated most of the times.

The reserves chain is not profitable

Most of the interviewed producers indicated that there is not any economical advantage in getting directly involved in the reverse chain. The most direct benefit would be an improved brand image perception by customers but this can achieved by participating to other initiatives meant at protecting the environment. The producers that gave this answer mainly sell to end users (B2C sector), meaning that products are geographically dispersed and performing collection of the disposed products would be very cost demanding. Furthermore, the producer does not have direct contact with its customers since sales occur via a distribution channel. Therefore also in the case of commercial returns or EoU products, meaning products with a potential high residual value, the producer is not involved. This does not mean that EoU products are not reconditioned and remarketed, in fact there are, but other actors are involved in the process.

Avoid eroding new sales and avoid getting involved in the reuse market

Other reasons often indicated are avoiding eroding new products sales, preventing confusion regarding the company's main marketing message and avoiding ruining the company image. For instance, entering the market of second hand products can compromise the company image if any problem occurs (high failure rate of second hand products, second hand products sold in markets where there are no environmental regulations).

There is an already well organised network for returned products and it is not our core business

In some cases there is an already well organised network for product returns with specialised actors that are able to perform reconditioning at very low costs. In this case, the return flow is profitable but it is not considered by the producer as part of its core business. In these circumstances, the concept of core competencies plays a relevant role. Even though the reverse flow is profitable, it is not convenient for the producer of the forward chain to integrate the reverse flow because other service chains specialised in recovery can achieve better economies of scale and higher efficiency.

The volume of returned products does not justify a direct involvement

In this case, even if a new product is bought, user's tendency is to keep the old one (typically mobile phones are not returned but kept for secondary uses). This is the reason indicated by Nokia Corporation which registers a limited retuning rate of mobile devices and the returned fraction is intercepted by the other actors.

8.5.4 The Second Research Question - Integration: Conclusions

The second research question interrogates on the possibility of integrating the forward and the reverse flows. The reason to investigate the integration issue has been given by the part of the supply chain management literature that invokes integration, coordination and other forms of collaboration as a way to achieve a superior competitive position.

We have supposed that the level of integration is affected by the level of involvement of the original manufacturer in the reverse chain and the level of performed in-house versus outsourced reverse activities.

A metric for each of the two criteria has been defined in order to assess the level of integration. The level of outsourced activities has been quantified with: high medium, low and none while the level of involvement with none, collective contracting, individual contracting, individual recovery and vertical integration.

The analysis has proven that:

- The majority the reverse activities are outsourced.
- The level of involvement is characterised by individual contracting in the case of the value driven reverse chain and collective contracting in the legislation driven reverse chain.

The producers have indicated four reasons that motivate their very low or non-existent involvement in the reverse flow: the unprofitable reverse flows, the protection of market shares, the low volumes of product returns and the necessity to concentrate on core processes.

Concluding, what emerges more frequently are two distinct flows, where the demand of the forward flow becomes the supply of the reverse one, the actors are different, and strategic objectives diverge. While the essence of supply chains is to create and provide value, reverse chains have the objective to recover value and/or comply with environmental regulations. These distinctive and different primary goals seem to not call for integration.

8.6 The Third Research Question: Profitability versus Costs

As stated in Chapter 1, §1.2.3, interest was also inspired by the part of the literature that mainly addresses "reverse" as a cost for companies instead of a business opportunity. Reverse logistics is often counted in terms of costs for completing the product offering or for complying with environmental regulations. By saying that we assume the point of view of the producer in order to evaluate the profitability of the chain, the profit in this context is considered as the net operating profit previous taxes (profit = revenue – operating costs – cost of the employed capital).

All instances presented in this study are profitable for one or more of the involved actors. LDRC is profitable for logistic providers and recycling companies. VDRC-I.2 is profitable for the service logistics provider. Only the VDRC-I.1 is profitable for both the service logistics provider (Geodis) and the producer (Alphabeta).

8.6.1 LDRC, legislation driven reverse chain

The chain is not profitable for the producer. The reason why the chain is implemented and managed is to comply with the WEEE Directive. In the optimal situation, the revenue generated by the sale of recycled raw materials would be able to compensate the total costs of the chain. At the moment the producers pay a fee which covers collection, transportation, treatment and operational costs. Indeed, during a interview with a major recycling provider, it emerged that the fee paid by the producers is mostly needed to cover operational and transportation costs since the revenue generated by the sale of recycled raw materials already exceeds the recycling costs for some of the product fractions and will soon exceed the recycling costs for almost all of them (Table 46).

Fractions	Revenue
Equipments containing CFC (cooling systems)	Negative
White goods	Positive
Equipment with CRT (cathode ray tubes)	Negative
Lamps	Negative
Household appliances	Positive
IT equipment	Positive

Table 46 – Revenue value stream per products fractions.

By enhancing the recycling technologies and reducing transportation and operational costs, it might be possible in the future to obtain a system which is able to auto-sustain itself.

8.6.2 VDRC.I.2, value driven reverse chain, instance 2

The chain is not profitable for the producer. The reason why the chain is operated by the logistics service provider is to offer the disposal service to different customers, mainly business users and producers (IBM, Banca Intesa-Sanpaolo, Samsung, Dade Behring, Vodafone, Cisco, Electrolux). Even though part of the received products can be reconditioned and remarketed, the customer does not receive any of the related profit.

8.6.3 VDRC.I.1, value driven reverse chain, instance 1

The chain is profitable. What makes the chain profitable for the producer? First of all, the variety of reworked products is not unlimited and the chain is structured in order to provide a dedicated service for a known range of products. Tooling and personnel skills are flexible enough to rework all products within that product variety range but not suitable to rework other kinds of products. Returned products have a high and, to a certain extent, a fairly well known residual value. Returned products are leased products that have been on use for a certain period of time and unless improper use has occurred during the using life cycle, the residual value is known beforehand. The Asset Recovery Center in Mainz does not know precisely in advance the content of the incoming shipments. Only the product family of the incoming goods is known, but once the returned products are identified, the costs for reconditioning are very well known and products for which the costs of reconditioning go over the cost limits are not reworked. The loss of value over time is also known and it is approximately 2-5% a month. This allows both the logistics service provider and the customer to take the necessary actions in order to avoid loosing an important fraction of the residual value that can be recovered and therefore tightly control the lead time. Incoming volumes saturate the

reworking capacity and picks are afforded by adding additional personnel. This allows achieving economies of scale in remanufacturing. A prerequisite is the existence of a second use market. And the price the secondary market is willing to pay to purchase the reconditioned products should be high enough to generate a profit after all costs are covered. Costs are not only reconditioning costs but also the costs for transportation.

Summarising, in the case of the VDRC-I.1 the profitability is ensured by several factors:

- – a limited variety of reconditioned products
- – known and high product value
- – known rate of value loss over time
- – fixed costs limits for reconditioning: over certain costs, reconditioning is not convenient and therefore not performed
- – the plant reworking capacity saturation
- – the existence of a second use market

The following section presents a simple model to assess the reverse chain profitability.

8.6.4 How to Assess Profitability

A simple model can be provided in order to assess the profitability of the reverse chain. The model is contextualised in relation to the case VDRC.I.1.

If we consider:

Q	The total quantity of leased products.
c	The percentage of the total quantity of leased products returned after use, in general smaller than 1 (not all leased products are returned, the customer might buy the leased product for a discount price).
$(1-c)Q$	Leakage, the quantity of leased products which are not returned.
cQ	The total quantity of leased returned products.
R	The percentage of leased products that can be reconditioned.
rcQ	The total quantity of reconditioned products.
$(1-r)cQ$	The quantity of returned products which cannot be reconditioned and is sent to disposal.
CL	Costs limit imposed by the customer.
C_{rec}	Reconditioning unit cost. C_{rec} cannot exceeds a certain cost limit CL, C_{rec} < CL.
C_{tra}	Transportation unit cost (supposed equal for outbound ad inbound

	transportation).
C_{dis}	Disposing unit cost.
P_1	Unit price for reconditioned products.
P_2	Unit price for remarketed products.
$rcQC_{rec}$	Total reconditioning costs.
cQC_{tra}	Total transportation costs (inbound and outbound).
$(1-r)cQC_{dis}$	Total disposing costs.

With:

Profit for Geodis, $PF_G = rcQP_1 - cQC_{tra} - rcQC_{rec} - (1-r)cQC_{dis}$

Total costs = $cQ\,[\,C_{tra} + rC_{rec} + (1-r)C_{dis}]$

Profit for Alphabeta, $PF_A = rcQP_2 - rcQP_1$

The producer Alphabeta is invoiced by Asset Recovery Center in Mainz according to contractual agreements. If we assumed that Alphabeta is invoiced on the basis of the reconditioned volumes (rcQ), the process is profitable for Geodis if:

$$P_1 > \frac{C_{tra} + r(C_{rec} - C_{dis}) + C_{dis}}{r}$$

While C_{tra} and C_{dis} can be considered fixed, C_{rec} varies according to the kind of received product and the "amount" of reconditioning the product needs.

The process is profitable for Alphabeta if:

$$rcQP_2 - rcQP_1 > 0, \text{ i.e., } P_2 > P_1$$

If C_{rec} exceeds CL, the reconditioning is not authorized since Alphabeta should pay a price higher than P_1 and this would ruin the profit for Alphabeta.

8.6.5 The Third Research Question - Profitability: Conclusions

The third research question has considered if the reverse chain can be profitable and for who. All instances presented in this study are profitable for one or more of the actors involved. However, by assuming the point of view of the producer, only the

refurbishment process performed by the Asset Recovery Center in Mainz results profitable for the producer.

Considering that the customer Alphabeta invoiced by Asset Recovery Center on the basis on the reconditioned volume, the process results profitable for the customer if the remarketing price is superior to the price paid for the reconditioning service. Since the price paid for reconditioning depends from the reconditioning costs, the customer has fixed a certain costs limit over which reconditioning in not authorised.

8.7 Linking the Three Research Questions

The following session examines the possible links between the three research questions on the basis of the hypothesis given in Chapter 1.

8.7.1 The Link Between the First and Second Research Questions

In Chapter 1, §1.4, it has been supposed that:

- Proposition 5. The higher is the product residual value, the higher is the level of integration.

- Proposition 6. Recovery options such as remanufacturing or refurbishment (recovery options for high products residual value) can re-utilize to some extent production facilities (integration) calling for synergies and economies of scale.

Proposition 5 suggests a possible link between the product residual value and the level of integration between the forward and reverse chains.

In particular, a high level of product residual value would call for integration and vice versa, low product residual value would not call for integration.

What emerges is that in the case of very high product residual value, i.e., VDRC.I.1, the level of integration is limited (Table 47).

In VDRC-I.2, the Recovery Center receives disposed products which can have high or low residual value but in any case, the level of integration is very low. LDRD confirms that low product residual value corresponds to low or no integration (Table 48).

Therefore Proposition 5 is only partially confirmed since we do not have encountered any instance of high product residual value combined with a high level of integration.

Proposition 6 presumes that recovery options for high product residual value can re-utilize to some extent the production facilities of the forward flow. However, reconditioning has proven to have a high level of specificity both in terms of tooling and personnel skills, and none of the instances confirms the assumption.

	Outsourced or in-house performed activities	Level of involvement of the producer
VDRC-I.1	Level C	Level 3

Table 47 – The low level of integration of VDRC.I.1. Level C corresponds to only marginal activities performed in-house and level 3 corresponds to individual contracting, low level of organisational capabilities and no tangible assets.

	High product residual value	*Low product residual value*
High level of integration	-	-
Low level of integration	VDRC-I.1 and VDRC-I.2	LDRD and VDRC-I.2

Table 48 – High/low product residual value versus level of integration.

8.7.2 The Link Between The Third Research Question and Questions 1 and 2

Proposition 7 (Chapter 1, §1.4) has presumed a causal link between the first and third research question:

- Proposition 7. The profitability of the reverse flow is influenced by the reserve supply chain structure. When the "right" reverse supply chain structure is implemented, the possibility to extract most of the total product residual value is higher and therefore profitability increases.

The evidence that emerges from the analysis supports the argument. In §8.4.3 the right reverse supply chain has been identified according to the primary objective the reverse chain has to provide. In particular, if the primary goal is cost savings, the chain has to be efficient, and vice versa, if the primary goal is reducing lead time and eliminates delays, the chain has to be responsive. In LDRC and VDRC-I.2, the chain is not profitable for the producer and in both cases efficiency is the primary target. Vice versa, the VDRC-I.1 that represents a chain which is profitable for the producer, responsiveness is pursued (Table 49).

	Efficient reverse chain	Responsive reverse chain
Profitable chain		VDRC-I.1
Not profitable chain	LDRC, VDRC-I.2	

Table 49 – The relation between reverse chain profitability and the reverse chain.

Proposition 8 has presumed a causal link between research questions 2 and 3:

- ▪ Proposition 8. Profitable reverse chains call for integration.

Since the level of integration has been characterised in terms of the level of involvement of the producer and the amount of performed in-house versus outsourced reverse activities, verifying if research questions 2 and 3 are linked correspond to verifying:

- – If the causal relation between profitability and the level of involvement of the producer is verified i.e., if profitable chains are chains which register a high level of producer involvement.

- – If the causal relation between profitability and amount of performed in-house versus outsourced reverse activities is verified i.e., if profitable chains are internalised.

In VDRC-I.1, even if the chain is profitable, the level of involvement of the producer is low as well as the amount of in-house performed reverse activities (only remarking is performed by the producer). Therefore relations 1 and 2 are not verified in case of VDRC-I.1.

In LDRC and VDRC-I.2, relations 1 and 2 are verified since the profitability of the chain is in existence and the level of involvement is low, as well as the amount of in-house performed reverse activities (Table 50 and Table 51).

	High level of producer involvement	Low level of producer involvement	None
Profitable chain		VDRC-I.1	
Not profitable chain		LDRC VDRC-I.2	

Table 50 – The relation between reverse flow profitability and the level on involvement of the producer.

	In-house performed reverse activities	Partially outsourced reverse activities	Totally outsourced reverse activities
Profitable chain	-	-	VDRC-I.1
Not profitable chain	-	-	LDRC VDRC-I.2

Table 51 – The relation between reverse flow profitability and in-house versus outsourced reverse activities.

8.8 The Loss of Product Residual Value Over Time: A General Framework

Reverse supply chain management has as its primary function the recovery of product value in the form of reconditioned products or recycled parts, components and materials. When there is no economic advantage in reconditioning and remarketing used products, the only option left is to recover value in the form of recycled materials or components. Additionally, it can be observed that recovery legislation intervenes whenever the market is not auto-regulating itself, providing a proper disposing opportunity.

However, even if there is the possibility of recovering value in the form of reconditioned products, the value can be lost due to time delays in processing. Therefore, producers and reverse chain actors should be sensitive to the loss of value of returned products suitable for reconditioning.

8.8.1 The General Framework: The Loss of Value Over Time

The loss of value of the returned product is related to time: the value decreases as time passes. However, the loss of value over time of returned products varies across industries and product categories. Consumer electronics such as PC can lose value at the rate of 1% per week, and this rate increases when the product approaches the end of its life cycle (Blackburn et al., 2004). In the case of refurbishing in the value driven reverse chain (VDRC-I.1), returned products lose value at the rate of 2-5% per month (0,5-1,25% a week). Other products such as dishwashers or washing machines lose value at a lower speed.

Figure 26 represents three products, products A, B and C that lose value with a different rate. A and B have the same residual value (v=v0) at the moment of return (t=t0).
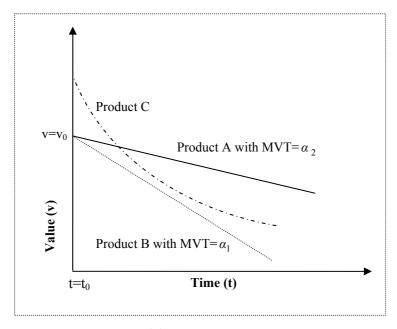
Figure 26 – The loss of value over time.

We use the definition introduced by Blackburn et al., 2004 in order to define the rate at which the returned product loses value: the marginal value of time (MVT). The MVT ($\beta\alpha$) is the variation of value over time and therefore it can be defined as:

$$\alpha = \text{MVT} = \frac{\Delta v}{\Delta t}$$

Δv = variation of value

Δt = time interval

In the case of a product value linearly decreasing as time passes (the examples of products A and B in Figure 26), the function f(x) can be expressed as:

$$f(x) = \beta v_0 - \alpha x$$

With:

- time t=x the independent variable

- the value v=f(x) the dependent variable

- x>0 (negative time no sense)

$f(x) = v_0$ for x=0

For $x \rightarrow 0$, MVT represents the first derivate:

$$\text{MVT} = \alpha = \lim_{x \rightarrow 0} \frac{f(x)}{x}$$

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Product B has a higher marginal value than product A; this means that product B loses value at a higher speed of product A. In Blackburn et al., 2004 product B is identified as a product with high marginal value of time; vice versa, product A is a low marginal value product. In mathematical terms this corresponds to:

$$\alpha_1 > \alpha_2$$

The product value can also decrease exponentially (product C in Figure 26):

$$f(x) = a^x + v_0$$

With:

- $0 < a < 1$ (exponentially decreasing)
- $x > 0$ (negative time no sense)
- $f(x) = 1 + v_0$ for $x = 0$
- $\alpha = MVT = (\ln a) a^x$

Exponentially or linearly, in any case, the value decreases over time. For simplicity, we assume that the value decreases linearly. It derives that we can associate a specific recovery option (§8.2.2.1) with time intervals (Δt): each recovery option is economically convenient within a certain time frame.

As time passes and product residual value decreases, the shift is from recovery options of first class (repair, refurbishing, remanufacturing) to recovery options of second class (cannibalisation, recycling).

Figure 27 represents the loss of value over time. The horizontal axis represents time passing. Time is related to the using life cycle, i.e., the time the product is on customer hands (§8.2.3). The vertical axis represents the value, which drops over time. Three cases are distinguished:

- CASE 1, which corresponds to the time frame and the related value for direct remarketing.
- CASE 2 which corresponds to the time frame and related value for the reconditioning options.
- CASE 3 which corresponds to the time frame for cannibalisation and recycling.

Commercial returns – CASE 1

If time $t = t_{start}$ is the moment of purchase, as soon as the product is on customer hands, the value starts to decrease. The product can be returned for any reason within 90 days after sale (the number of days changes according to national returns legislations). This is

the case of commercial product returns: the product flows back due to wrong delivery or wrong acquisition. The customer receives a credit for the returned product or he/she is entitled to have another product (item substitution). The internal $\Delta t1 = t_{90} - t_{start}$ is the time available for immediate remarketing. The time frame for remarketing is very limited and the only performed activities are testing and repacking. The product has lost only a limited amount of value (point P1 in Figure 27) and after testing and repacking the value is returned to $v_{90}r = v_{start}$ (point P2 in Figure 27).

The cases presented on this thesis do not particularly address the issue of commercial returns, but from one of the interviews, it emerged that commercial returns can be so time sensitive that they are handled within the forward logistics chain and within 2-3 days (laptops and related devices).

Reconditioning – CASE 2

After $t = t_{90}$ the product can be returned for repair (with or without warranty) or it can be definitely disposed of by the customer. The time interval $\Delta t2 = t_{last} - t_{90}$ is the time frame suitable for the recovery options of first class (repair, refurbishing, remanufacturing). Which of the three is pursued depends on the product residual value at the moment of return and the remarketing opportunities (original or second used market).

Remanufacturing is to recondition the product back to the "as new" status and it would not be convenient if the product does not re-enter the original market. Correspondently, repair would be most probably suitable if the time of return is not far from t=t90. For repair, refurbishing, remanufacturing (CASE 2 in Figure 27) the time frame to recover value is longer than in CASE 1. If the product is returned with a value $v = v_{last}$ (point P3 in Figure 32) reconditioning implies to raise value to a higher value $v = v_{lastr}$ (point P4 in Figure 32). The reconditioned product (CASE 4) also loses value and the MTV of a reconditioned product is higher that the MTV of new product.

In our study, reconditioning is the recovery option of VDRC-I.1, the value driven reverse chain for refurbishing jointly managed by Geodis Asset Recovery Centre Mainz and the customer Alphabeta. The product is dismissed after leasing (3-5 years of usage) and process lead time is 14 days. Refurbished products are placed in the second use market via a broker network.

Cannibalisation, recycling – CASE 3

The last form of value recovery (CASE 3 in Figure 27) is parts/components harvesting (cannibalisation) and materials recycling and residuals are sent to incineration or landfill. When time for reconditioning has passed ($t > t_{last}$), the process time becomes irrelevant and cost efficiencies predominant. The product configuration is lost and value is recovered in the form of recycled raw materials, parts, components.

CASE 3 corresponds to cannibalisation and recycling. Cannibalisation is the main recovery option that characterised the VDRC-I.2, the process performed by the Geodis Plant in Busnago that mainly performs product dismantling and retrieval of parts and components. Process lead time is quite irrelevant and temporary depot of returned products is accepted. Recycling is instead represented by the LDRC which recovers value by materials recycling.
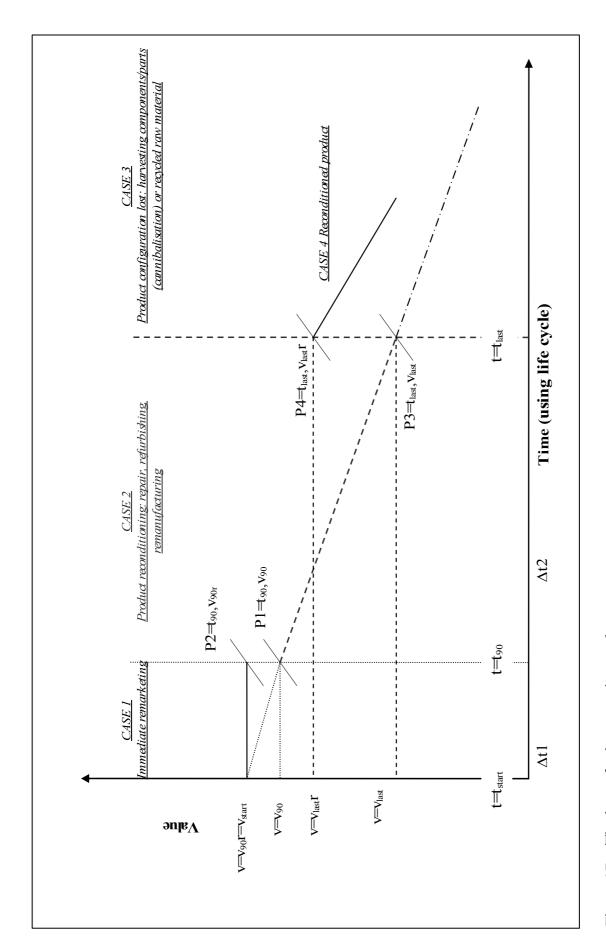
Figure 27 – The loss of value over time and

8.8.2 The Right Reverse Chain and the Marginal Value of Time

In §8.4.3 we have presented the relation between efficient versus responsive reverse chain and the product residual value. By introducing the concept of MVT, the relation can be further elaborated: it is not only important the residual value at the moment of return (high or low product residual value) but also the speed at which the returned product loses value (high or low MTV).

In Blackburn et al., 2004 it is suggested that for returned products with high MVT, the reverse supply chain should be responsive and for products with low MVT the reverse chain should be efficient. Since efficient efficiency is synonymous of a centralised structure and responsiveness of a decentralised structure, for returned products with low MVT, centralisation should be promoted. Instead, decentralisation facilitates fast asset recovery by early product diagnosis; therefore decentralisation with the preponement logic should be preferred for high MVT products.

To be more precise, referring to Figure 26, products A and B are examples of a high marginal value of time product (Product B) and low marginal value of time product (Product A) with:

$$\alpha_B > \alpha_A$$

As Fisher's matching-mismatching matrix has been reinterpreted for high and low product residual value, an equivalent matching-mismatching matrix can be constructed for high and low MVT (Table 52). The matrix suggests that high MVT calls for a responsive reverse chain and low MVT for an efficient reverse chain. Low α demands economies of scale and centralised structure; high α calls for preponed product evaluation, decentralised structure, trade-offs between investments to achieve responsiveness, and high costs for duplication of specialised resources.

	Efficient Reverse Chain	Responsive Reverse Chain
Low marginal value products = high α value	Match: economies of scale in processing and transportation, postponed product evaluation, delayed product recovery, centralised structure	No Match
High marginal value products =low α value	No Match	Match: preponed product evaluation, higher costs, decentralised structure

Table 52 – The matching/mismatching matrix for low/high marginal value products versus efficient/responsive reverse supply chain (adapted from Blackburn et al., 2004).

These considerations only partly apply to the case studies under analysis.

VDRC-I.1 deals with high MVT, however we encounter a centralised reverse chain that assures responsiveness by controlling the lead time at that expense of less than full truck loading in transportation.

In VDRC-I.2, retuned products do not have such a known and defined MVT since the mix of returned products is very diversified. Products that have been in used for longer time have a lower chance being reconditioned and remarketed. Value is recovered by harvesting valuable parts and components. High MVT products are instead reconditioned. Again, centralisation is promoted.

In LDRC, matching is instead accomplished. The MVT is low, the chain structure is centralised, economies of scale are pursued in processing and transportation and product evaluation is not even performed.

8.9 Conclusions

The chapter has answered the three research questions and it has provided the argumentations to accept or reject the research propositions.

Furthermore, a general framework to evaluate the relation between the loss of value over time and the recovery option has been presented.

The three research questions of this study correspond to:

- Research question 1: Is it possible to provide indications to guide the elaboration of the design strategy for the reverse chain? How to determine the reverse chain structure?
- Research question 2: Are the forward and reverse chain integrated? Is integration a major concern?
- Research question 3: Is the reverse chain profitable?

We have supposed that the product residual value determines the recovery option that determines the reserve chain structure and the analysis has demonstrated that:

- Low product residual value (LDRC) is associated with second class recovery options (recycling and energy recovery).
- High product residual value (VDRC-I.1) is associated with first class recovery options (reconditioning and remarketing).

When the recovery option is recycling, time is not relevant, the primary objective is reducing costs (efficiency) and the chain is centralised.

When the recovery option is reconditioning, time is primarily relevant, and trade-offs between process costs and time efficiency is necessary.

Previous literature (Blackburn et al., 2004) suggests that when the product residual value is high, early product differentiation is necessary and therefore the chain is decentralised. We have demonstrated that this is not true in case of low returned volumes and high quality standards.

In order to evaluate the level of integration, the level of involvement of the producer, and the level of in-house versus outsourced reverse activities have been considered. It has been proved that integration is not a major issue and the level of integration is very low even when the reverse flow is profitable for the producer. Producers have motivated with different reasons why they do not consider relevant to internalise the reverse flow and prior to anything else, they have declared that they do not consider "reverse" profitable. We have encountered only one reverse chain which is profitable for the producer.

Previous literature (i.e., Blumberg, 2005) has claimed that in the case of reconditioning, the integration allows the re-utilisation of production facilities in the reconditioning process. This has not been confirmed: high specific equipment and personnel are required for reconditioning.

A general framework that considers the link between the loss of product value over time and the viable recovery option, as well as the link between the rate at which the product loses value and the suitable reverse chain structure has been presented. The framework constitutes a useful paradigm to assess the most viable recovery option when the product residual value and the MVT are known.

The next chapter (Chapter 9) interprets the results on the light of two major theoretical frameworks (transaction costs and institutional theory).

Chapter 9. A Theoretical Interpretation

"If I am not for myself, then who is for
me? And if I am not for the others, then
who am I? And if not now, when?"
Rabbi Hillel

9.1 Introduction

The purpose of this chapter is to proceed from the findings emerged from the analysis (Chapters 8 and 9) to "theory marching". The results of the analysis are interpreted through the lenses of two major theories: theory of firm (transactions costs economics), and organisation theory (institutional theory). It is neither the intention of this study to provide a literature review of the developments of those theories, nor to review any of the critiques moved to them.

Hundreds of works that discuss these theories and all their elements, from many different perspectives and in relation to the many fields in which they have been applied can be found. For the objective of this chapter, only the theories' main tenets are concisely outlined as well as the reasons for selecting them to interpret the findings.

§9.2, 9.3, and 9.4 present the theories in the following order:

 – transaction costs economics theory
 – institutional theory

In §9.4 and 9.5 findings are interpreted on the light of the chosen theories.

9.2 Transaction Costs Economics Theory

The origins of transaction cost theory dates back to 1937 (Coase, 1937). However it took until the middle 1970s to become influential in both research and public policy with the works of Arrow, 1974 and especially Williamson, 1975.

Arrow's work focused on four major themes:

- The concept of rationality of individuals and society further developed by Simon, 1957 and Williamson, 1981.
- Asymmetric information between two contractual parties
- The agenda of the organisations
- The concept of authority and responsibility

However, it is mainly Williamson's first work dated 1975 which has provided the foundations for the theory. In effect, Williamson is deemed as the father of the theory and he has been the first scholar to make explicit the link between transaction costs economics (henceforth TCE) and firm strategy (Foss, 2003). The following sections present the main tenets of TCE theory.

9.2.1 Assumptions

The theory assumptions are bounded rationality, and opportunism.

9.2.1.1 Bounded Rationality

Bounded rationality refers to the fact that people have limited memories and limited cognitive processing power. People can neither assimilate all the information at their disposal nor can accurately work out the consequences of the information.

The concept of bounded rationality was firstly used by Simon, 1957 reflecting the fact that economic actors, presumed to be rational, are not hyper-rational, rather they experience limits in formulating and solving complex problems.

9.2.1.2 Opportunism

Opportunism refers to the possibility that people will act in a self-interested way. People may not be entirely honest and truthful about their intentions; or they might attempt to take advantage of unforeseen circumstances that give them the chance to exploit another party. Williamson does not assume that all people will act opportunistically all of the time. He merely assumes that some people will act opportunistically some of the time, and none can tell in advance who is an opportunist and who is not.

9.2.2 The Transaction and its Attributes

The theory focuses on "transactions and the costs that attend completing transaction by one institutional mode rather than another" (Williamson, 1975). The transaction, a transfer of goods or services is the basic unit of analysis (Williamson 1981). The central claim is that the transaction should be carried out in such a way that minimise the costs involved. The main criterion should be "economizing on costs" which "takes two parts: economizing on production expenses and economising on transaction costs" (Williamson 1979). If the transactions costs are negligible, "buying rather than making will be the most cost effective means of procurement". "Economizing on transactions costs essentially is reduced to economizing on bounded rationality while simultaneously safeguarding the transaction in question against the hazard of opportunism" (Williamson 1979). As transactors increase the investments in specialised assets, the transaction costs increase because the transactors should 1 it for other transactions decreases; this means that bilateral dependency is greater, and contracting hazards between parties are present. The reason why asset specificity is critical is that once the investment has been made, buyer and supplier come to operate in a bilateral exchange relation for a considerable time period and the value of the investment on other uses will be much smaller. The more a resource is specialised, the lower is its value in alternative uses.

The second and third dimensions (frequency and uncertainty) affect the choice of the form of governance. Frequency can be characterised as one time, occasional and recurrent. Uncertainty refers to the availability of the product or the service exchanged in the transaction (Cox, 1996).

The frequency dimension refers strictly to the buyer activity (Williamson 1979). A way to see frequency is if the transaction is recurrent enough in order to permit the costs of the specialised governance structure to be recovered.

9.2.3 The Governance Structures

Three alternative forms of governance are identified (David and Han, 2004):

- Market
- Hybrid
- Hierarchy

Each mechanism of governance is supported by a different form of contract law and each employs its own system of coordination.

The market governance corresponds to the classical contract law, where the identity of the transacting parties is unimportant and no dependency exists between them. Market

transactions are governed by formal terms, interpreted in a legalistic way and characterised by hard bargaining.

In the hybrid form, the parties taking part to the transaction maintain autonomy but are bilaterally dependent. The parties' identity matters in the sense that each could not be replaced with another one without costs (idiosyncrasy). Hybrid forms are supported by neoclassical contract law, which is more adaptive than the classical contract law.

Hierarchy is the most elastic and adaptive form of governance of the three. The parties resolve disputes internally.

9.2.4 How Frequency, Uncertainty and Specificity determine the Form of Governance and the Contract

TCE retains that there are rational economic reasons for choosing the means of governing transactions called the "discriminating alignment hypothesis" (Williamson, 1991) which asserts that transactions with different attributes are aligned with different governance structures, i.e., the governance form that minimises the costs of the transaction should be the one preferred. The principal attributes of the transaction are asset specificity, uncertainty and frequency. How to they impact the form of governance and the related contract (Williamson, 1979; Table 53)?

Non specific, recurrent or occasional transactions correspond to the market as form of governance and classical contract as form of contracting. When asset specificity is low, the market is the governance form no matter what the level of uncertainty since transactions can be easily rearranged.

- Mixed or idiosyncratic, occasional transactions correspond to the trilateral form of governance and neoclassical contract as form of contracting.
- Mixed, recurring transactions correspond to the bilateral form of governance and obligational contract as form of contracting.
- Idiosyncratic, recurring transactions correspond to the unified form of governance (vertical integration) and internal organisation as form of contracting. Asset specific transactions happening frequently require a constant monitoring effort in the market, while those that occur only occasionally do not need to be attended and do not deserve the costs of bureaucracy for establishing a hierarchy (David and Han, 2004).

		Investment characteristics		
		Non specific	**Mixed**	**Idiosyncratic**
Frequency	**Occasional**	Market governance (Classical contracting)	Trilateral governance (Neoclassical contracting)	
	Recurrent		Bilateral governance (Relational contracting)	Unified governance

Table 53 – Matching governance structure with commercial transactions (Williamson 1979).

Trilateral, bilateral and unified forms of governance are to various degrees specialised governance structures. The definitive feature of the trilateral (neoclassical contract) is the inclusion of a third party, or arbitrator, to deal with disputes arising from changes in trading circumstances, while the key element of the bilateral, obligational contract appears to be its emphasis on the continuity of the relationship and the need for adaptability to changing circumstances (Carter and Hodgson, 2006).

Combining frequency, specificity and uncertainty, the suggested forms of governance are (Carter and Hodgson, 2006):

1 Vertical integration – the vertical integration is efficient in case of
   – Recurring transactions, idiosyncratic investments and uncertainty is high or medium.
   – Recurring transactions, mixed investments (medium asset specificity) and uncertainty is high.
2 Trilateral governance mechanism or neoclassical contracting is efficient in case of :
   – Occasional transactions, idiosyncratic investments and medium uncertainty.
   – Recurring transactions, mixed investments and medium uncertainty.
3 Bilateral governance mechanism or obligational contracting is efficient in case of:
   – Recurrent transactions, mixed investments and intermediate uncertainty.

Trilateral and bilateral governance mechanisms correspond to hybrid governance structures.

9.2.4.1 Transaction Specificity and Form of Governance

Transactions with low asset specificity should be undertaken in the market, transactions with intermediate asset specificity in the hybrid form of governance, and transactions with high asset specificity in hierarchical form of governance.

9.2.4.2 Uncertainty and Form of Governance

When asset specificity is low, market is the governance form no matter with 'what the level of uncertainty is. When asset specificity is present in a not trivial way, continuity between the transaction parties is important and both market and hierarchical governance modes are preferable than hybrids because hybrid forms can not develop unilateral adaptations.

9.2.4.3 Frequency and form of governance

The frequency of the transaction acts in a similar way. Asset specific transactions happening frequently require a constant monitoring effort in the market, while those that occur only occasionally do not need to be attended and do not deserve the costs of bureaucracy for establishing a hierarchy.

Therefore:

- As asset specificity increases, the transaction costs in the market governance increase.
- As asset specificity increases, hybrids and hierarchies are preferred over markets; with very high specificity, hierarchy becomes the preferred form of governance.
- When asset specificity is present in a non trivial way, increasing uncertainty renders markets preferable to hybrids, and hierarchies preferable to both hybrids and markets.
- When both asset specificity and uncertainty are high, hierarchy is the most cost effective form of governance.

9.2.4.4 Safeguards

Transaction costs increase when asset specificity increases for risk of opportunistic behaviour. To protect against opportunism, the transactor may employ a variety of safeguards (Dyer and Singh, 1997). The safeguard is the controlling mechanism which has the objective of bringing about the perception of fairness or equity among the transactors. The most common employed mechanism of safeguard is the contract. And with the increase of asset specificity, the costs of contracting increase as transactors attempt to write a more complex contact with contingency clauses. However, given bounded rationality, it is impossible to consider all the complexity in all contractual

relevant respects (Radner, 1986). Therefore, incomplete contracting is the best that can be achieved.

Other sources of safeguards are relational or goodwill trust, and reputation.

9.2.4.5 Why the Theory was chosen

The theory has been chosen to interpret the findings since it provides insights into the circumstances where product recovery transactions are more efficient by having the producer vertically integrated, rely on third parties or develop hybrids such as consortia, alliances or joint ventures. Secondly, the theory provides a way to analyse the consequences of one party investing in transaction specific assets. Because such investments lose value when applied to other transactions, whoever makes this investment becomes dependent upon the other party. The TCE has already been applied in the analysis of recovery management in Toffel, 2004.

9.3 Institutional Theory

Philip Selznick, an American sociologist is considered as the father of the institutional theory. He put in evidence that organisations adapt not only to their internal groups, but also to the values of the external environment and society, a consideration that is perceived as most obvious nowadays (Selznick, 1957).

The organisation environment is conceptualised as an entity that lies outside the boundaries of the organisation. It influences organisational outcomes by imposing constrains and demanding adaptation in order to survive. The organisation faces uncertainty about the demand of the environment and, at the same time, it experiences dependency on the multiple and various elements of the environment itself (Hatch, 1997). The general environment comprises of several forces: the social and cultural sectors, the political, legal and economic pressure, technological and physical influence.

The environment forces the organisation in two ways. First, demand comes from technical and economic aspects, and it requires organisations to produce and exchange their goods and services in the market. Second, demand poses social and cultural requirements that force organisations to play a certain role in the society and to establish and maintain a certain outward appearance. Environments dominated by technical and economical forces reward organisations when efficiently and effectively supplying goods and services; vice versa, environments dominated by social and cultural forces reward organisations when conforming to values, norms, rules and beliefs of the society.

The institutional theory recognises in the social and cultural elements the predominant factors of the influence of the environmental on organisations. The theory analyses how

external pressures force organisations to become more similar and focused in achieving similarities, and the process by which organisations become institutionalised.

According to Scott, 1987, the aspects of the environment through which institutional influences operate include: regulatory structures, government agencies, laws and courts, professions, interest groups and public opinion.

The focus of organisations on being similar determines homogeneous organisational forms and practises (DiMaggio and Powell, 1983). The concept that best summarises the process of homogenization is called isomorphism and it has been defined by Hawley in 1968: "isomorphism is a constraining process that forces one unit in a population to resemble other units that face the same set of environmental conditions". For DiMaggio and Powell, 1983 the process of homogenization takes place in the organisational field defined as any recognised area of the institutional life. In the initial stage of their life cycle, organisational fields show great differences but they slowly converge towards homogenisation once the field is well established.

Conforming to institutional demands wins social support and ensures survival not necessarily because the organisations become more efficient, but because it complies with accepted conventions: "It is important to notice that each institutional isomorphic process can be expected to proceed in the absence of evidence that it increases internal organisational efficiency… organisations are rewarded for being similar to others in their fields" (DiMaggio and Powell, 1983), i.e., social legitimacy becomes one of the key input resources such as the labour or the raw materials. Even further, the access to the other input resources might be conditioned by social acceptance.

9.3.1.1 The Three Mechanisms of Institutional Isomorphism

DiMaggio and Powell, 1983 distinguish three mechanisms through which institutional isomorphic changes occur: coercive isomorphism that derives from political influence and the problem of legitimacy; mimetic isomorphism resulting from standard responses to uncertainty, and normative isomorphism associated with professionalisation. Coercive isomorphism derives from formal and informal pressures carried out on organisations by other organisations upon which they depend from and by cultural expectations in society. Such forces can be exerted through persuasion, invitation to join shared behavioural models, government mandates, laws and regulations. Coercive forces are typically used by governments through regulations (Hoffman and Ventresca, 2002).

Mimetic isomorphism responds to the need to cope with uncertainty. When goals are ambiguous or when the environment creates uncertainty, organisations may model themselves imitating other organisations. Modeling is then a response to uncertainty. Typical models used for instance in production are lean or agile manufacturing or JIT in sourcing.

Normative isomorphism comes from professionalisation which is the collective effort of members of an occupation to define the conditions and methods of their work to control the production of procedures (Larson, 1977 and Collins 1979).

One stream of institutional theory, neo-institutionalism, attempts to move beyond the mere recognition of the social and cultural foundations of institutions to describe the process by which practises and organisations become institutions (Scott, 1987) and view the ways that organisations manage institutional pressures as a source of differentiation (e.g., Woodward, 1965, Child and Keiser, 1981). Differentiation can stem from a different perception of changing institutional forces.

Institutional theory represents the most common framework applied to analyse the consequences of environmental legislations (Herold, 2007) and it has been used to comprehend how environmental practises disseminate amongst originations and what can be done to encourage the diffusion (Jennings and Zandbergen, 1995).

9.3.1.2 Why the theory has been chosen

In particular for our purpose, the theory has been chosen since two main aspects of the theory arise from the case analysis:

- The homogeneity of the behaviours and frames of reference the producers have adopted to comply with the WEEE legislation.
- The homogeneity that legislation has forced in the industry electrical and electronic industry on a European level.

Beside, Pfeffer and Slanick, 1978 have observed that politically determined environments are characterised by political decision makers that often ignore the consequences of their actions. The first aspect is present in the study: the European commission, the main political decision maker is quite unaware of the consequences of the adopted legislation. Institutional theory has already been applied for investigating how environmentalism develops within an industry over time, the impact of regulation on environmental practises and how environmental practises spread amongst organisations (Jennings and Zandbergen, 1995).

Interpreting the findings in the light of the institutional theory is only meaningful in the case of the LDRV. The process of institutionalisation is not present in the value driven reverse chain.

9.4 The Interpretation of Findings According to TCE Theory

The main tenets of TCE theory are (Williamson, 1979):

- the transaction as unit of analysis
- the governance structure which is the institutional framework within which the integrity of transactions are negotiated and executed
- the frequency of the transaction as well as the level of uncertainty
- the level of specificity of the asset involved in the transaction.

We use these main elements of the theory in order to interpret the evidence emerged from the analysis.

9.4.1 The Theoretical Contribution of TCE in the Analysis of the Legislation Driven Reverse Chain

In the legislation driven reverse chain (LDRC) we recognize different transactions.

In the B2C sector, we identify two main transacting levels:

- The transaction between the producer and the collective scheme identified as transaction T1 where the buyer of the service is the producer and the supplier is the collective scheme;
- The transaction between the collective scheme and the recycling companies, identified as transaction T2 where the buyer of the service is the collection scheme and the supplier is the recycling companies.
- In the B2B sector, we identify one level of transacting:
- The transaction between the business user and the recycling companies, identified as transaction T3, where the buyer of the service is the business user and the supplier is the recycling company.

We consider the frequency, the level of asset specificity and the level of uncertainty for each transaction.

9.4.1.1 The Transaction between the Collective Scheme and the Producer

Transaction 1 is represented by the service provided by the collective scheme to the producer. The transaction is not recurrent - the producer signs yearly contracts with the collective scheme. The contract specifies the costs of the service and the producer's obligations as well as the collective scheme obligations. The uncertainty of the transaction is very low. No specific investments carried out in relation to the transaction are registered on the supplier side: collective schemes can provide the same service to a large variety of producers. Investments on the buyer side are as well not specific. Indeed, investments in human assets are made to train personnel which follow the contractual process with the collective scheme and acquire expertise on WEEE related issues, but they can be easily redeployed in transacting with another collective scheme without losing most of their value.

In these conditions (non specific investments, occasional transaction) Williamson's theoretical framework suggests the market as governance structure; however we notice that the contract ties up the producer and collective scheme for a time frame that does not correspond to the time frame of spot or recurrent classical contracts of the governance mode of markets. Annual contracts bind the producer, the buyer of the service, with the collective scheme, the supplier of the service: such a long time frame might create some sorts of specificity in the transaction even if not tangible. This might imply that in the subsequent year, the producer will not pursue the economising strategy and try to bargain for the best price available in the market, but rather continue the relationship since some sort of dependency has intervened.

There might also be the case of the supplier investing to some extent in specific assets. This happens for instance when the collective scheme is not only dedicated to administrating the process but acquires the containers/cages for collection. This might imply a sort of hostage situation for the supplier.

Anyway, regardless of these particular circumstances, we can definitely assert that the governance mode of the transaction is the market, or quasi-market.

9.4.1.2 The Transaction between the Collective Scheme and the Recycling Company

Transaction 2 is represented by the service provided by the recycling company to the collective scheme. The frequency of the transaction is low and determined by contractual agreements usually signed on an annual basis.

The supplier, the recycling company, has high investment costs to set up the recycling facilities; however investments are not specific to the transaction since recyclers' investments are not tied up to a particular buyer or processed product. Eventually, adding recycling capacity for the purpose of servicing a collective scheme could represent a specific investment of the transaction. The buyer does not have any specific assets investment related to the transaction as it can contract different recycling companies. Uncertainty is low.

Williamson's theoretical framework suggests the market as governance structure.

9.4.1.3 The Transaction between the Business User and the Recycling Company

Transaction 3 is represented by the service provided by the recycling company to the business user. The transaction occurs occasionally only when the business user needs to dispose of electrical or electronic appliances. Uncertainty is high and the transaction is characterised by spot contracts and bargaining. The recycling company that offers the service at the lower cost complying with environmental legislation is the one chosen by

the business user. Non specific assets are assigned to the transaction neither by the supplier nor by the buyer. Again, Williamson's theoretical framework suggests the market as governance structure.

Table 54 summarises the characteristics of transactions T1, T2 and T3, and according to Williamson's framework, the suggested governance mode would be the market.

This is actually the governance structure adopted in practise, therefore, the legislation driven reserve chain is aligned with the theoretical assumptions of TCE theory. However, it is also observed that a tendency towards vertical integration in the case of recycling companies that constitute a collective scheme in order to assure certain fixed incoming volumes to their recycling plants. This is particularly relevant in situations of exceeding recycling capacity.

	Frequency	*Asset Specificity*	*Uncertainty*	*Governance mode*
T1	occasional	non specific	low	market
T2	occasional	non specific	low	market
T3	occasional	non specific	high	market

Table 54 – Transactions in the LDRC, their characteristics and the governance structure.

9.4.2 The Theoretical Contribution of TCE in the Analysis of the Value Driven Reverse Chain

In the value driven reverse chain (VDRC) we recognize different transactions corresponding to: the refurbishment process executed by the service logistics provider Geodis for the customer Alphabeta (VDRC-I.1) and the dismantling process carried by service logistics provider Geodis for different customers (VDRC-I.2).

In VDRC-I.1, the transaction interests one single customer and the service logistics provider. High idiosyncratic investments are present both for the buyer and the supplier (high asset specificity).

Investments on the supplier side are highly idiosyncratic in the most two important aspects: physical and human (Williamson, 1979).

Site asset specificity is related to the plant proximity of the supplier to the buyer and this is not present: the Asses Recovery Center (ARC) is located in Mainz and it services products leased by Alphabeta and returned from 15 different countries. Idiosyncratic investments in human capital are definitely present: the personnel at the ARC Mainz are trained to refurbish products leased by Alphabeta. Special purpose equipment is needed to for the process (idiosyncratic investments in physical assets). Besides, required high

quality standards and short lead time reinforce the necessity of specialised human and equipment capital.

For the buyer, the level of asset specificity is lower compared to the supplier and it is determined by the fact that "the buyer cannot turn to alternative sources of supply and obtain the same favourable conditions since the costs for unspecialised capital is presumably great" (Williamson 1981). The buyer invests on human capital for contracting and revising standards, procedures and lead time with the supplier. Therefore the buyer is locked into the transaction just as the supplier is.

The transaction is recurrent and level of uncertainty is intermediate and mainly related to possible continuous process improvements. In such conditions, Williamson's paradigm calls for vertical integration but the observed governance structure is different and it is closer to the bilateral governance mechanism with obligational contracting. The bilateral, obligational contract assures the continuity of the relationship and, at the same time adaptability to changing circumstances, "the focus being on quantity rather than price adjustments" (Carter and Hodgson, 2006). And this is exactly the requirements of the transaction.

Alphabeta was vertically integrated since the ARC in Mainz is a former Alphabeta Recovery Unit. Alphabeta signed a contract with Geodis in 2002 in order to externalise the refurbishment of small machines (laptops, desktops) but it is still integrated for the refurbishment of bigger machines (servers). The decision to externalise the refurbishment process of laptops, desktops and related devices cannot be explained in terms of the TCE theory, and it most probably related to the core competences paradigm and it might find an explanation in the light of resource based theory.

Since high transaction specific investments occur, TCE foresees the most exposed transactor may employ safeguards to protect against opportunism. The mechanism of safeguards used in this transaction is the contract. Also relational and goodwill trust are present.

In the VDRC-I.2, the transaction interests many different customers and the service logistics provider. Idiosyncratic investments are present for the supplier.

Site asset specificity is not present: the Recovery Center (ARC) is located in Busnago and it services customers located all over Italy. Idiosyncratic investments in human capital are present since the personnel are trained to perform dismantling and eventually repair and refurbishment; special purpose equipment is needed (idiosyncratic investments in physical assets).

For the buyer there are no specific assets investments. The buyer can easily consult other recovery centers in order to buy the same service. Since the idiosyncratic investments in physical assets interest only the supplier, there is no vertical integration and contract

agreements are neoclassical and the governance mode is trilateral. Finally, the transaction is occasional but also yearly contracts can be signed, and level of uncertainty is low (Table 55).

	Frequency	Asset Specificity	Uncertainty	Governance mode
VDRC-I.1	recurrent	high – idiosyncratic investments	intermediate	bilateral governance, obligational contracting
VDRC-I.2	occasional	high – idiosyncratic investments for the supplier, non specific investments for the buyer	low	trilateral governance mode, neoclassical contracting

Table 55 - Transactions in the VDRC, their characteristics and the governance structure.

9.4.3 The Theoretical Contribution of TCE in the Analysis: Conclusions

We sum up the considerations emerged in the interpretation of the findings by means of the TCE theory by applying the matrix of supplier-buyer relationship developed by Bensaou, 1999. The scholar found a set of management variables that tend to co-vary and interact with one another in creating effective supplier relationships.

In particular, he discovered that the level of specific investments made by either partner significantly correlates with relational practises such as strategic partnership, long term relationships, mutual trust and cooperation. These investments are difficult to transfer to other relationships and may lose completely their value when redeployed in another relation. Bensaou segmented the sample of his research according to buyer's specific investments and supplier's specific investments. He recognized as specific investments, both tangible as well as intangible investments. Buyer's tangible investments can be represented by buildings, tooling, and equipment while intangible investments are people, time and efforts spent in learning supplier's practises and routines. Supplier's tangible investments are plants, warehouse locations, specialised facilities and dies, while intangible investments are for instance sending engineers to work with the customer in the design and prototyping phases, or develop an information system compatible with the buyer.

By combining low versus high investments on supplier and buyer sides, he identified four possible different situations of buyer-supplier interactions:

- The strategic partnership: both parties have invested highly idiosyncratic assets in the relation;

- The market exchange: both parties have not developed specialised assets. They can work together using general purpose assets and they can turn to the market place and easily shift to another business partner.
- The captive buyer refers to the asymmetric relation in which the buyer is kept hostage by a supplier which is free to switch to another customer. Hence, only the buyer has invested in specific assets dedicated to the relation.
- The captive supplier refers to the asymmetric relation in which the supplier is kept hostage by a buyer which is free to switch to another supplier. Hence, only the supplier has invested in specific assets.

Three of the four possible supplier-buyer interactions identified by Bensaou are present in our study (Figure 28):

- The strategic partnership, in the case of the the VDRC-I.1
- The captive supplier in the case of the VDRC-I.2
- The market mode in the case of the LDRC.

Buyer specific investments	Captive buyer (buyer hostage): none	Strategic partnership: **VDRC-I.1**
	Market exchange: **LDRC**	Captive supplier (supplier hostage): **VDRC-I.2**
	Supplier's specific investments	
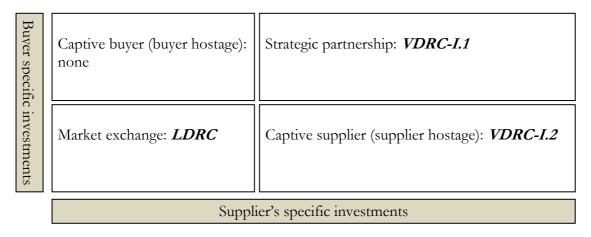
Figure 28 - Portfolios of buyer-supplier relationships (adapted from Bensaou, 1999).

9.5 The Interpretation of the Findings according to the Institutional Theory

Institutional theory analyses the process by which firms become institutionalised and the ways companies have to differentiate in responding to institutional pressures (neo-institutionalism).

As already mentioned, the theory can provide insights in the analysis of the legislation driven reverse chain that for many aspects confirm the prevision of the theoretical institutional paradigm.

9.5.1 The Theoretical Contribution of the Institutional Theory in the Analysis of the Value Driven Reverse Chain

The theory asserts that "once disparate organisations in the same line of business are structured into an actual field (a recognised area of institutional life), powerful forces emerge that lead then to become more similar" (DiMaggio and Powell, 1983). The same authors have also hypothesized that "the greater the extent to which the organisations in a field transact with agencies of the state, the greater the extent of isomorphism in the field as a whole". The standards imposed by the state confirm the behaviour of all competing companies. This hypothesis is fully confirmed in our study of the legislation driven reverse chain (LDRC).

The theory prescribes three types of forces that promote isomorphism: coercive, mimetic and normative. Of the three, the one that applies in the case of the LDRC is the coercive mechanism and partially the mimetic one.

The coercive isomorphism results from both formal and informal pressures. In DiMaggio and Powell, 1983 it is argued that "in some circumstances, organisational change is a direct response to government mandate: manufacturers adopt new pollution control technologies to conform to environmental regulation". In the case of the LDRC, the WEEE-Directive, and the related state legislation, has not introduced changes in technologies but have enforced a way to comply with the regulation. Producers are called to take over the responsibility of the recovery system in a collective way, each of them contributing according to the market share. It is not even a problem of gaining legitimacy in the social context since producers are obliged to fulfil the legislative requirements.

Isomorphism is displayed in the system the producers have chosen to respond to the legislation. Collective schemes have been formed and participants share the same complying mechanisms: the all behave in the same way, they all sign into a collective scheme and they all limit their involvement to the payment of an annual fee. If this is the most effective or efficient way to answer to the legislation is not questioned, neither by the producers, nor by the institutional organisms that are appointed to monitor and control the system. It has to be said that collective contracting is the most obvious mechanism to answer to a legislation that does not reward brands or producers according to their environmental commitment.

Partially, also mimetic pressure has intervened. Mimicry occurs in the presence of uncertainty, a powerful force that encourages imitation. "When goals are ambiguous or when the environment creates symbolic uncertainty, organisations may model themselves on other organisations" (DiMaggio and Powell, 1983); when an organisation faces a problem with ambiguous causes and unclear solution, imitation may be a viable solution. In this case, it is said, that the organisation "models" itself following the

example of another organisation. Mimicry is present in the LDRC in the sense the new comers imitate the behaviour of the existing producers and small, medium size companies have modelled their response by copying the mechanism established by the major producers, that are, by the way, also the founders of two major collective schemes.

The mechanism of isomorphism cannot be observed in the case of the VDRC.

9.6 Conclusions

The chapter has considered how two main theoretical paradigms, TCE and institutional theory can contribute to the interpretation of the findings that have emerged from the case analysis. TCE has provided an understating of the kind of relationships and contracts determined by the level of specificity of the assets dedicated to the transaction. One governance structure has been encountered in the case of the transactions taking place in the LDRC, and two different governance modes in the VDRC.

Institutional theory can only be applied to the LDRC. The legislation driven chain have proven to confirm the high degree of isomorphism in the case of state regulations.

The next chapter summarises the findings emerged from the analysis and the theoretical interpretation and it draws the final conclusions.

Chapter 10. Conclusions

"Reality is the only truth"
Aristotle

10.1 Introduction

This chapter concludes the dissertation and discusses the findings and their implications. The chapter consists of three major parts.

The first part summarises the results of the analysis (Chapters 7 and 8) and the theoretical interpretation (Chapter 9). The analysis has been carried out in three segments: Chapter 7 considered the two case studies of this thesis, the legislation driven and value driven reverse chains, and has emphasized their specific aspects; Chapter 8 responded to the research questions by combining the evidence that has emerged from the cases; research propositions have been accepted or rejected on the basis of the results. Chapter 9 has attempted to interpret the results by applying the frameworks provided by TCE and institutional theory.

The second part of this chapter provides indications and recommendations to the main stakeholders of the recovery chain: producers, service providers and policy makers. From a managerial point of view, normative results are relevant in order to assess and value the implications of the reverse flow within the context of supply chain management.

The third and last part presents: 1. the theoretical contribution of this thesis to the field of supply chain management, 2. the limits of the study and indications for further research.

10.2 The Findings

This section intends to summarise the case analysis (Chapter 7), the cross case analysis (Chapter 8) and the theoretical analysis (Chapter 9).

10.2.1The findings of the case analysis

Chapter 8 considered the two cases of the study, the legislation driven reverse chain and the value driven reverse chain. The analysis outlined considerations and insights derived from the case investigation and it provided the foundations for the cross case analysis. We hereby summarise the main points and the distinctive characteristics from the cases.

10.2.1.1 The Legislation Driven Reverse Chain

The legislation driven reverse chain (LDRC) was implemented in order to support the disposal process of electrical and electronic waste. The dismissed products are returned by end users (the B2C sector) and business users (the B2B sector). The chain was enforced in order to comply with WEEE European Directive and it was configured on the basis of a national legislation that follows the major part of the guidelines provided by the Directive. The only relevant difference concerns the grouping of the 10 product categories defined by the Directive into 5 fractions.

Since the system principally deals with historical waste and there is no possibility to sort the disposed appliances according to brands, collective responsibility (extended producers responsibility) is enacted by the Directive.

Therefore producers have responded with collective contracting mechanisms. The system presents collective schemes that are differently configured: from pure administrative schemes to schemes that are backed by recyclers.

The logistics of the process entails:

– Collection
– Consolidation
– Transposition
– Treatment

Collection is decentralised in order to reach capillary the end users. Consolidation is performed before shipping to the recycling plants. Since the chain that does essentially recover waste, the main objective is efficiency and low costs.

The chain presents a number of critical factors and drawbacks.

1. While reuse should be the favoured recovery option, the chain has failed in promoting reuse since the system is not capable of efficient sorting. Therefore, all collected appliances are conveyed to recycling.

2. The system is administrated by the collective schemes. Collective schemes are called to collect the disposed appliances from the municipal collection stations and from the distribution channel (wholesalers/retailers). The allocation of the collection points to the collective schemes is performed on the basis of two principles: each collective scheme should collect a fraction of the waste proportional to the market share of its members and in order to promote free competition, collection points are assigned on a random basis. This clearly promotes competition but does not support the main principle of protecting the environment since there is no consideration related to the proliferation of the transportation and logistics infrastructure.

3. Contrasting stakeholders' objectives are not mitigated by a strong authority: while municipalities aim at minimising investments for collection areas forcing frequent picking, the transporters and recyclers aim at full truck loading and limited investments in logistics infrastructures.

4. Even though the Directive promotes all the DfX techniques and it encourages producers to re-design their products in order to facilitate recovery, it does not provide any incentive to reward the producers that adopt these methodologies.

10.2.1.2 The Value Driven Reverse Chain

The value driven reverse chain case study has considered two different flows:

–   Remanufacturing/refurbishment of PCs equipment (VDRC-I.1, value driven reverse chain, instance 1) Remanufacturing is performed centrally in Mainz. The recovery center is almost completely dedicated to one single customer, Alphabeta. The center treats only leased products dismissed by customers when the leasing contract expires. All activities are tailored to comply with customer needs. It is the customer which imposes lead time, quality standards and remarketing policies. Reconditioning assets are customer dedicated.

–   The pre-treatment of end-of-utilisation products in Busnago, Italy (VDRC-I.2, value driven reverse chain, instance 2). To the contrary of refurbishment, the pre-treatment service is performed for different customers all located in the Italian territory. The same service (end of use or end of life disposal) is offered to a wide range of customers.

Both processes aim at recovering value in the form of products (remanufacturing) or in the forms of materials, components, parts (in the dismantling process). The first flow is

time dependent since it deals with products that lose from 2 to 5% of their value every month. Processing lead time is crucial (14 days). The chain structure is centralised.

The second flow is not so time depended since it deals with a variety of product conditions. Products in good condition are refurbished and remarketed while faulty, damaged products with low residual value are dismantled and parts/components are recovered. The chain structure results in being' decentralised considering the European market but it is nationally centralised (the recovery center serves customers located in the Italian territory). The choice to focus on the national level depends on the fact that products are acquired as waste and to obtain cross country authorisations for waste transportation is quite overwhelming.

10.2.2 The Findings of the Cross Case Analysis

The study has addressed the following research question:

- Research question 1: Is it possible to provide indications to guide the elaboration of the design strategy for the reverse chain? How to determine the reverse chain structure?
- Research question 2: Are the forward and reverse chain integrated? Is integration a major concern?
- Research question 3: Is the reverse chain profitable?

10.2.2.1 The First Research Question: The Reserve Supply Chain Configuration

The first question has interrogated on the possibility to provide guidelines for identifying the "right" reverse supply chain structure.

The paradigm proposed by Fisher in 1997 has constituted the departing point to answer this research question. Fisher observed that the analysis of the demand pattern is fundamental to determine if a product is innovative or functional and consequently determine the proper supply chain design strategy. The "role" that demand pattern has in Fisher's model is replaced by the product residual value in the case of the reverse chain: it is the product residual value that has to be taken into consideration when determining the reverse supply chain structure: the paradigm that the product residual value determines the recover option and the recovery option determines the configuration of the reverse supply chain holds true. In combination with the product residual value, also the speed at which the product loses value has to be considered (MVT).

The case studies have proven that:

- Recovery options of first class (repair, refurbishment, remanufacturing) have to be considered for returned product with high residual value.

- Recovery options of second class (recycling, incineration) have to be considered for returned product with low or non residual value.

- The recovery option determines the phases of the recovery process, the chain configuration, and the type of actors involved and their relations.

- Even though in literature decentralisation is suggested for returned products with high product residual value and high MVT, centralising or decentralising the reverse chain structure is much more related to the size of incoming volumes and the need of expertise (dedicated tooling and specialised personnel) in reconditioning than any preponement strategy.

- The efficient reverse supply chain has been proven to be the right match for products with low residual value and low MVT (legislation driven reverse chain) while the responsive supply chain has been proven to be the right match for high product residual value and high MVT (value driven reverse chain).

Table 44 in Chapter 8 presents the conclusions related to the first research question.

10.2.2.2 The Second Research Question: the Integration between the Reverse and Forward Chain

Another objective of the PhD thesis has been to contribute to the issue of integration between the forward and reverse chain since, according to literature, the integration would lead to synergies. Obviously, whenever possible, synergies are preferable since they can provide different forms of efficiency. However, it has been proven that the flows analysed in this thesis are not integrated and the entire concept of closed loop supply chains has not been confirmed by this study.

In order to assess the level of integration, two evaluation criteria have been considered: the involvement level of the original manufacturer in the reverse chain and to which extent reserve reverse activities are performed in house.

In order to evaluate the two criteria, two metrics have been defined:

The level of internalisation of the reverse activities	The level of involvement
Level A – Most or the total of the reverse activities performed in-house.	Level 1 – No involvement
Level B – Some of the reverse activities performed in-house.	Level 2 – Collective contracting
	Level 3 – Individual contracting
Level C – Only marginal activities performed in-house.	Level 4 – Individual recovery
	Level 5 – Vertical integration
Level D – None.	

The study has proven that:

- The level of involvement of the producer is limited to collective contracting in the case of the LDRC and it is characterised by individual contracting in the case of the VDRC-I.1 and the VDRC-I.2.

- Most of the activities related to the reverse chain are outsourced even when the original manufacturer holds a direct interest in the reconditioning process and the process generates a profit (VDRC-I.1). In the VDRC-I.1 the producer maintains the control over the process and directly performs remarketing. In the VDRC-I.2 (value driven reverse chain, flow 2) and in the LDRC (legislation driven reverse chain) activities are completely outsourced.

Table 45 in Chapter 8 summarises the conclusions of the cross case analysis in relation to second research question.

A further research objective has been to identify the main reasons why the reverse and forward chain are not integrated, at least for the cases considered in this project. Producers have provided several motivations:

- The reverse chain is not profitable.
- Producers are focused on protecting the market of new sales and they are worried to compromise their reputation if something goes "wrong", especially if they do not directly control the reuse market and the reconditioned products end up in countries where there are not environmental legislations.
- There is already a well organised network for returned products where specialised actors are able to perform reconditioning achieving economies of scale and high efficiency.
- The low volume of product returns does not justify an investment on recovery facilities.

10.2.2.3 The Third Research Question: Profitability versus Costs

Interest was also motivated by the part of the literature that mainly addresses reverse logistics as pure cost instead of a business opportunity. Very few contributions present grounded cases of profitable reverse chains (Chapter 1, §1.2.3) and they do not concentrate on the industry of electrical and electronic appliances, which instead offers a valuable opportunity to confront recovery chains that have legislation as main driver and recovery chains that have profit has main driver.

To evaluate profitability means to identify for whom the chain is profitable. By taking the point of view of the producer, only the VDRC-I.1 results profitable for the producer while the VDRC-I.2 is profitable for the service logistics provider and the LDRC is profitable for the recyclers.

Several factors have been identified in order to determine if a reverse chain can represent an opportunity for profit generation for the original producer:

- The variety of reconditioned products is limited
- The product residual value is known and high
- The product loses value over time at a known rate
- Costs limits are defined in order to approve or reject reworking
- The reworking capacity has to be saturated
- Last, but maybe the most important, the existence of a second hand market.

Moreover, a framework to evaluate profitability contextualised to the VDRC-I.1 has been presented. The VDRC-I1 is profitable if the price of remarketing is higher than the price paid by the producer to the service provider for reconditioning. Since the price paid for the service is fixed and decided by contract while the costs for reconditioning vary according to the status of the leased product, the producer has imposed a costs limit barrier over which reworking is not authorised.

10.2.2.4 The Link between the Research Questions

A set of propositions has been suggested in order to evaluate possible correlations between the research questions:

- Proposition 5. The higher the product residual value, the higher is the level of integration.
- Proposition 6. Recovery options of first class (remanufacturing, reconditioning and repair) can re-utilise to some extent the production facilities.
- Proposition 7. The profitability of the reverse flow is influenced by the reserve supply chain structure.
- Proposition 8. Profitable reverse chain call for integration, vice versa, non profitable reverse chain do not support integration.

It has been proven that proposition 5 is only partially confirmed since even though the product residual value is high, as in the case of the VDRC-I.1, the level of integration is very limited. The level of involvement of the producer is characterised by individual contracting and only remarketing is directly performed by the producer.

Proposition 6 has been proven to be false since reconditioning is characterised by a high level of specificity for both machinery and personnel. The level of specificity of all reconditioning processes does not support the consideration that by integrating the forward and reverse chain, the product knowledge acquired in manufacturing could be transferred to the remanufacturing process and production facilities employed in manufacturing could be redeployed in remanufacturing.

The evidence emerged has instead confirmed proposition 7; in particular, if the primary goal is efficiency, the chain has to be efficient, and vice versa, if the main goal is reducing lead time and eliminate delays, the chain has to be responsive.

Propositions 8 is confirmed in case of non profitable reverse chains while, for the profitable reverse chain of this study, the VDRC-I.1, the level of integration is low.

10.2.2.5 The Marginal Value of Time

A general framework to evaluate which is the most appropriate recovery option according to the product residual value and the loss of value over time (MTV) has been proposed. It has been suggested that:

Each recovery option is economically convenient within a certain time frame

The time slot available for reconditioning shrinks for products with high marginal value of time, i.e., products that lose value at (insert 'a') high rate.

10.2.3   Analysis Conclusions

The Recycling Chain – LDRC

The WEEE recycling chain collects and treats products with low or no residual value. Time is not relevant and efficiency is the priority for all phases. The chain is to some extent centralised (consolidation points) but it has to guarantee capillary collection, therefore collection points are numerous and highly decentralised. The level of integration is almost nonexistent: producers are not engaged in reverse activities and they comply with the legislation by collective contracting. The flow is profitable for the recyclers.

The Refurbishment Chain – VDRC-I.1

Early product differentiation and short lead time would suggest, according to Blackburn et al., 2004 a decentralised structure in order to achieve responsiveness. On the contrary, the refurbishment process is centralised, product testing is performed at arrival and not locally, and all returned products are centrally processed. The responsiveness is nevertheless guaranteed since the entire lead time for both transportation and order completed is 14 days.

The service is "shaped" according to customer needs and requirements. The refurbishment unit almost totally serves one single customer and centralisation responds to the customer's requirements of high uniformed quality standards (multiple decentralised units could implement different procedures), and guarantees proper volumes to fully load the capacity and the control of the remarketing process.

The level of integration is very limited and confined to the control that the customer maintains over the refurbishment process. Only one task is directly performed by the customer: the remarketing of the refurnished products.

The flow is profitable for the producer.

The Disassembly (pre-treatment) Chain – VDRC-I.2

The disassembly process is quite general in terms of treated products, services and customer variety. Since the main activity is dismantling, parts harvesting and raw materials recycling, efficiency is more important than responsiveness. Temporary depot and late treatment are allowed. In order to reach economies of scale in transportation and recovery, we would expect a centralised structure. Centralisation is only partially achieved (national level) since approval for waste cross countries transportation implies delays and complicated procedures.

The level of integration is almost nonexistent. The flow is profitable for the service logistics provider.

10.2.4   *The Theoretical Analysis*

In Chapter 9 we presented TCE and the institutional theory. The findings have been evaluated in the light of these two theoretical frameworks. It emerged according to TCE, that:

- – VDRC-I.1 is characterised by bilateral governance (obligational contracting), intermediate uncertainty, idiosyncratic assets and recurrent transactions.
- – VDRC-I.2 is characterised by trilateral governance mode (neoclassical contracting), low level of uncertainty, idiosyncratic assets and low frequency.
- – The market mode is present in the case of the LDRC, with low uncertainly, non specific assets and low frequency.

Institutional theory has proven to be relevant only in the case of the LDRC. In LDRC, coercive isomorphism is evident in the way the producers have chosen to respond to the legislation. Collective schemes have been formed and participants share the same complying mechanisms and the same behaviour.

Partially, also mimetic pressure is present: new comers imitate the behaviour of the existing producers and small, medium size companies have modeled their response copying the mechanism established by the major producers.

10.3 Practical Implications

This section provides indications and recommendations to the main stakeholders of the recovery chain: producers, service providers and policy makers.

10.3.1 Recommendations for the Producers

This study provides a useful framework for producers that want to determine a successful strategy for product returns. The starting point should be to determine which product returns flows directly impact the company and segment them according to the product residual value.

For low residual value, where the only viable option is to recover value in the form of recycled materials, the most appropriate strategy is to take part to collective recycling platforms. Since this is not a profitable process for the producer and it is largely regulated, the producer can only follow the provisions determined by the authorities and eventually take part in the definition process of the norms in order to provide indications for an effective implementation of the recycling system. Major producers, for instance, have taken part in the definition of the WEEE Directive providing useful insights to the policy makers. Another option is to consider the output of the recycling process as a source of complementary procurement. For instance, one collective scheme formed in Denmark, LWF, incorporates as members most of the major producers on lighting equipment. The producers of this industry utilise the glass recovered from their disposed products as an alternative source of raw material to feed the production.

For intermediate and high product residual value, the main issue would be to determine if a direct involvement of the producer would be convenient and eventually evaluate if there is any actor in the market that can provide the recovery service at a convenient price. For some sectors (for instance mobile phones, La Repubblica, 2006) there is an already well organised network for product returns with specialised actors that are able to perform reconditioning at very low costs. Even though the reverse flow is profitable, it is not convenient for the producer to integrate product returns simply because other service chains specialised in recovery can achieve better economies of scale and higher efficiency.

If managers instead consider the option of internalising the product returns flow, evaluations should be strictly related to overall company strategy. For this issue, the concept of core competencies as viewed in Resource Based theory (RBV) could assist managers in determining the most appropriate choice. Resource Based theory is founded on the paradigm that the firm should seek to gain ownership or access to valuable, rare, non-imitable, and non-substitutable resources. And resources are "valuable" when they

enable a firm to conceive and implement strategies that improve its efficiency and effectiveness. A key aspect of the theory is to determine if an activity requires idiosyncratic resources, and if this is the case, relying on external players is costly and the activities should be developed in-house (Poppo and Zenger, 1998). Instead for resources that can be traded in the market, investing in their creation does not determine a competitive advantage. Therefore, outsourcing decisions should be based on the evaluation of which in-house activities permit the exploitation of different knowledge, capabilities and routines already present in the firm. Therefore the key issue is to determine if the company already has a set of resources and capabilities that can be leveraged in product returns management.

Once the company has decided to directly engage in product recovery, whether the flow is internalised or not, managers should further determine if the MTV (marginal value of time) is high or not and therefore, "shape" the reverse logistics flow and reconditioning process accordingly. If the MTV is high, lead time should be reduced and delays eliminated.

There are other factors that might condition at various levels, the choice of whether to engage of not in product returns and to which extent. These factors are posed by the external environment, as already discussed in Chapter 9, § 9.3.1.1 (the isomorphic forces in institutional theory). Furthermore, the pressure of external stakeholders such as society, governments, industry associations and internal stakeholders as consumers and employees might also be relevant. For instance, rising public concern about environmental degradation contributes to influence customers on their purchasing decisions. Managers can be assisted in evaluating the importance of stakeholder pressure by the stakeholder paradigm (stakeholder theory) that focuses on identifying and understanding the role of stakeholders on companies' management. For managing stakeholders pressure what matters the most is to determine the stakeholders' reliance which is related to the cumulative number of stakeholder attributes such as power, legitimacy and urgency.

10.3.2 Recommendations for Logistics Service Providers

This study contributes to suggesting possible new opportunities of business for logistics providers. The advantage of logistics providers is that they already own the logistics infrastructure; therefore idiosyncratic resources can be leveraged for other activities, such as product returns.

In order to properly decide whether to engage in product returns or not, the logistics provider should be very well aware of its market position. We hereby present a possible framework for positioning derived from the literature.

10.3.2.1 A Positioning Framework

In Persson and Virum, 2001 we find an analysis of how logistics providers strategically position themselves within the competing arena. What the authors note is that:

- users are increasingly buying logistics services on an international level
- logistics is mainly outsourced
- the tendency is towards consolidation in the number of logistics suppliers.

Consolidation towards a lower number of logistics suppliers forces the logistics provider to provide complete and integrated services. The required service could span from design and implementation of the logistics network, to mere execution of the logistics processes.

In order to respond to the changes of customers demand, logistics companies have to reposition themselves by rethinking which strategy they want to pursue. By combining the theoretical perspectives of:

- how to develop and maintain a competitive advantage (Porter's paradigm or core competences and competitive advantage)
- how to position themselves according to distinct resources (RBV theory)
- how to manage relations and alliances

The authors provide a framework to detect the strategic position of a logistics provider and the directions for growth.

Positioning should aim at developing and maintaining a competitive advantage that can be variety based, needs based or access based. Variety based positioning is characterised by the choice of products or services variety rather than customer segments, meaning that the logistics provider decides to focus on a subset of industry products or services. A second positioning choice is represented by servicing most or all the needs of a particular group of customers. The third is segmenting customers who are accessible in different ways (for instance segmentation can be based on geographical criteria).

Positioning according to distinct resources is evaluated in terms of transaction costs, agency and contract theories that provide indications of which types of economy to achieve: downstream vertical integration, upstream vertical integration, horizontal integration and diversification. Downstream and upstream vertical integrations, better accomplished by alliances, permit the creation of a mechanism of governance advantage while horizontal alliances are the traditional path to exploit economies of scale and diversification economies of scope.

By combining the level of infrastructure ownership (defined as owned or not owned physical assets) and market position (needs versus variety based position), different types of logistics providers are identified (Table 56):

- third party logistics operators which use their physical assets to respond to specific customer needs;
- logistics operators which utilise their assets to perform a specific function offered to different customers segments;
- logistics integrators with limited physical assets; they operate as external logistics departments for one or several customers.
- logistics agents, which do not own physical assets and offer their knowledge based service to a wide range of customers.

	Physical assets based position	**Non physical asset based position**
Needs based position	Third party logistics operators	Logistics integrators
Variety based position	Logistics operators	Logistics agents

Table 56 – The logistics service providers and their strategic position (Persson and Virum, 2001).

In respect to this taxonomy, the logistics provider of this study, Geodis, presents aspects of at least three of the identified types. As forward logistics provider, the company is positioned as logistics operator: services (air and sea freight, transportation, distribution and express deliveries) are offered to different sectors (automotive, chemical gas, retail, consumer goods, high tech industries, luxury goods, healthcare and textile). The physical infrastructure is well developed in France (Geodis headquarters) while in the other countries they operate via partnerships.

When coming to reverse logistics, the two recovery units tend to be positioned differently, both in respect to forward logistics and between themselves. The refurbishment unit is needs based oriented: all activities are tailored to comply with customer needs. It is the customer which imposes lead times, quality standards and remarketing policies. Reconditioning assets are customer dedicated (transactions costs are in place) while transportation assets are partly owned, partly rented from local transportation companies (DFDS, a Scandinavian based logistics company is for instance utilised to deliver end of leased machines to Mainz from the Nordic countries). The dismantling unit is variety based positioned providing the same service (EoU or EoL disposal) to a wide range of customers. Transportation assets are rented from local transportation companies while processing assets are owned.

10.3.2.2 Recommendations for Logistics Providers: Conclusions

Geodis is not the only logistics provider that has decided to engage in reverse logistics.

For instance, another major logistics provider, DHL, already offer a variety of reverse logistics services and it is conducting different studies in different countries in order to assess the opportunity to expand the reverse logistics service portfolio, including the management of EoL products within the framework of the WEEE Directive. We just mention the case of DHL managing the return flow of Siemens's mobile network boards, even though it was only partially investigated because of time constrains. The reverse logistics service includes the swapping of the damaged board with a new one by a field operator, the transportation to a central depot (one in each country) and the subsequent problem solving to identify the entity of the damage and classify the boards according to the type of needed repair (repair of first level without hardware manipulation, repair of second level implying the substitution of damaged components and repair of third level which additionally requires welding). Only the repair of third level is outsourced, all the other activities are directly preformed by DHL. The same logistics provider is active in commercial returns and it directly performs the testing (quality control), the back-on-shelf processes, and remarketing via brokers for product returns which only has the packaging damaged. This service is offered to a variety of customers, including large retailing stores chains that return deliveries even if only the package is damaged. Once more, it is the logistics provider that identifies other sales channels to remarketed retuned products.

We therefore underline that the business opportunities for logistics providers are quite numerous and the ability to configure and offer different reverse logistics services comes back to positioning and leveraging of existing internal idiosyncratic resources.

10.3.3 Recommendations for Policy Makers

From a policy makers' point of view, this study offers some insights into what the current situation is within the electronic and electrical industry, and what issues producers are tackling. It also provides a base to analyse the impacts of different policy measures on companies. The most interesting application for policy makers is to analyse the results of the WEEE Directive implementation. The EU legislation is rather prescriptive and producers do not perceive to having many choices to comply or to accomplish any benefit from their efforts. This lack of options has lead companies to limitedly invest in organisational capabilities to monitor the legislation. The amount of organisational resources dedicated to the WEEE Directive is relatively high but employees are focused on legislative compliance due to the lack of options and the complexity of member state differences. Most producers in the EU are not looking at

ways to innovate to cut costs or generate revenues since WEEE compliance is not viewed as a business opportunity.

Despite the many indications contained in the Directive in order to promote design improvements to extend the product life cycle and facilitate recycling, producers are not able to contextualise these indications mainly because they are not rewarded for their efforts and they do not have any incentive for pursuing higher levels of recovery.

Probably, the most positive environmental improvement and highest efficiency can be realised by rearranging the product oriented scope (10 products categories) towards a treatment category oriented scope. The use of different criteria based upon more environmentally focused aspects related to collection and treatment categories can contribute to more environmentally relevant targets for collection, recycling, recovery and treatment. These considerations should be taken into consideration by the EU Commission and policy makers for further revisions of the legislation.

10.4 Theoretical Contribution

This study also contributes to the understanding of the supply chain management field.

Supply chain management has received increasing attention over the last twenty years but limited contributions have been produced in order to evaluate product returns management, and it is still an open question whether it is correct to consider reverse supply chain as a separate stream apart from the forward supply chain or not, in other terms, if the reverse flow is part of the forward supply chain in the logic of closing the loop. Krikke et al., 2004 presents closed loop supply chains as an obvious answer to efficient management of both forward and reverse flow. Supply loops strategies are presented in Geyer and Jackson, 2004. Schultmann and Sunke, 2006 support the concept of closed loop supply chains controlled by the manufacturer.

This study does not support the argument of closed loop supply chains since most of the time, the return flow cannot be considered as part of the original supply chain (the original producer is only involved in controlling the reverse chain in VDRC-I.1). What emerges more frequently are two distinct flows, where the demand of the forward flow becomes the supply of the reverse one, the actors are different, and strategic objectives diverge. The most obvious reasoning is that while the essence of supply chains is to create and provide value, reverse chains have the objective of recovering value and/or comply with environmental regulations. These distinctive and different primary goals seem not to call for integration.

Other studies have stressed the importance of using centralised centres which offer both reverse and forward logistic services or at least the need to adopt a holistic approach to

forward and reverse supply chains (Rogers and Tibben-Lembke 2001, Prahinski and Kocabasoglu 2006, Bernon and Cullen 2007). These contributions base their argumentations on the analysis that centralisation guarantees large returned volumes and minor investments in infrastructures.

This study supports this argument and it has demonstrated that even though some authors propose decentralisation in order to achieve preponement benefits (Blackburn et al., 2004), it is mainly considerations regarding large returned volumes which are predominant (VDRC-I.1).

In Prahinski and Kocabasoglu (2005), one of the research propositions links the selection of the returns facilities (third party logistics providers versus in-house centralised returns centres) with competitive priorities. It is argued that the best match is achieved when capabilities are aligned with business and functional strategies. Consequently, the competitive priorities of a reverse supply chain should affect the returns facility selection and the common tendency is to outsource reverse to third party logistics providers, both in Europe and US.

This study is a further confirmation that producers prefer to outsource reverse logistics services to specialised logistics providers. Externalisation and outsourcing could mean companies poor understanding of reverse logistics, in terms of costs versus potentialities (therefore firms prefer to manage returns as variable costs) but also a confirmation that companies focus on their core business.

Previous literature have identified factors that impact the profitability for producers involved in recovery (product characteristics in De Brito and Dekker, 2004; Lund 1998 and Rose at al., 2002), the existence of markets for recovered products (Thierry et al., 1995; Guide and Van Wassenhove, 2003; Geyer and Jackson, 2004), characteristics of return flow (Guide and Van Wassenhove, 2001; Ferrer and Whybark, 2003) and consumer behaviour (Mayers, 2001; Geyer and Jackson, 2004).

This study has demonstrated that the opportunity for profit generation for producers (VDRC-I.1) is related to previously mentioned factors but also:

- – The variety of reconditioned products
- – The product residual value
- – The loss of product value over time
- – Costs limits to approve or reject reworking

An interesting finding is the demonstrated relation between the product residual value and the recovery options with the reverse chain design strategy. This relation has been further elaborated by combining the paradigm offered by Fisher, 1997 and the one proposed by Blackburn at al., 2004.

Fisher's paradigm (Fisher, 1997) that suggests matching the supply chain with product typology (efficient supply chains for functional products and responsive supply chains for innovative products), has been reinterpreted for reverse supply chains and we have proposed a way to identify what is the most appropriate reverse chain design strategy according to the product residual value.

We believe that the general framework proposed in Chapter 8, § 8.8.1 which proposes that each recovery option corresponds to a certain time interval and the time interval shrinks with high MVT, represents a useful tool to elaborate a proper approach for managing different kinds of product returns.

Finally, institutional theory has not been often used in supply chain management. Institutional theory looks at how organisations' behaviour is affected by the external environment and it has provided useful insights to interpret the isomorphic behaviour of producers in the LDRC.

10.5 Limitations and Indications for Further Research

The thesis concludes providing the limitations of this study and the indications for further research. This project is limited in many ways as already indicated in Chapter 1, §1.6.

The focus is on the industry of electrical and electronic products. While focusing at an industry level helps to control extraneous variations and define the limits for generalisation (Eisenhardt, 1989), it limits the possibility to generalise the findings to other industries. In particular, the product residual value and the MVT that have been determinant in analysing the cases of this study, might result in being quite irrelevant for other industries that are not so affected by rapid technological changes and fast loss of product value. Therefore, further research should consider other industries in order to expand the applicability of the results.

Companies involved in the study are manufacturing companies, logistics service providers and recycling companies. In particular, it emerges that logistics providers might be very important key players within the reverse supply chain management arena (Skjøtt-Larsen and Halldorsson, 2000). We suggest that further research should investigate deeper the role of these actors that might benefit from the favoured position of owning the logistics infrastructure and complex knowledge of the mechanism involved in logistics. It is not a fortuity that major logistics providers, as mentioned in §10.3.2.2, are investigating how to enhance their reverse logistics portfolio in different countries. From this study it also emerged that different units of the same logistics company are positioned differently. This observation opens up further research

questions on the effectiveness of combining different strategies within the same company.

Furthermore, the thesis focuses on two types of returns: EoL and EoU. Returns as manufacturing returns, product recalls, by-products, packaging returns, commercial returns have been excluded in these study. Further research could address these types of returns and utilise the proposed general framework to characterise them. In particular, commercial returns might be an interesting area to exploit to enhance the understating of the reverse supply chain since they might confute some findings of this study. For instance, commercial returns might be characterised by a higher level of involvement of the original manufacturer.

This thesis has contributed to identify the factors that affect the profitability of the reverse chain but also the chance to assess that the level of profitability is strictly linked with the possibility of measuring the performances of the reverse chain. Economic metrics for efficiency and effectiveness are largely explored in the supply chain management literature; in fact, an entire research stream is devoted to performance management systems but one major limitation emerges (Morgan, 2007): the focus is on a single company (focal company) or at the broadest on the dyadic relation (i.e., buyer-supplier). How to proceed in identifying meaningful metrics to access an entire chain? Since the reverse flow has high impact in terms of benefits guaranteed to the environment, how to combine performance indicators for economic and environmental efficiency? We believe that a very interesting area for further research in reverse supply chain could be the definition of a performance management system that combines economic and environmental indicators. Since it results difficult to measure the performances of an entire chain (Morgan, 2007), combining indicators of different nature could be even more complex. In Cagno et al., 2007 several management, operational and environmental indicators have been provided. It could be interesting to test the proposed list of indicators in a reverse supply chain management context. We propose a framework that could be utilised to proceed in the elaboration of a comprehensive performance management system (Figure 29).

Furthermore, it remains a striving process to identify which reverse supply chain approach better fits product and producer settings: the simplifications adopted to provide a general framework (in Chapter 8, §8.8.1, it has been for instance assumed the decline of product value to be linear) needs to be proven to not overrun validity, in other words, we suggest further validation with other cases.

Chapter 3 on methodology hopefully provided enough indications on the validity and reliability of this study. However, to conduct two case studies represents a limitation to generalisation, and the theoretical contribution can be too narrow or too complex. To mitigate this risk, we strived to collect a large amount of data and complement the case

studies with interviews and observation of other reverse flows, such as the one shortly presented in § 10.3.2.2. Furthermore, social desirability bias can be a risk when interviewing an organisation in relation to environmental issues. The attempt to eliminate this risk is a striving challenge. In this study, we tried to use multiple informants and different sources of information.

The thesis has used qualitative research and case studies as research technique, and it has considered two case studies with the motivation of addressing opposing situations, a legislation driven reverse chain and a value driven reverse chain. This approach has the advantage, as stated as Yin, 2003 that "if the subsequent findings support the contrasts, the results represent a strong start towards a theoretical replication and … vastly strengthening the external validity of the finding". Nevertheless, we suggest that further research should aim at theoretical replication by including other types of returns flow and also case studies that consider other returns flows of the same type of this study, i.e., other cases of value driven reverse chains and other cases of legislation driven reverse chains.
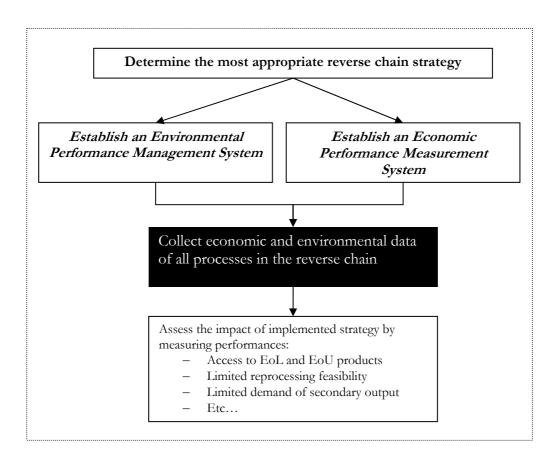
Figure 29 – A framework to process in the elaboration of a performance management system.

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Appendix I: The interviewed actors

Case study 1 – Interviewed actors – Denmark

Institutions

Type of actor	Institutional
Name of the organisation	The Danish Ministry of Environment
Job title of the interviewee	Assistant to the Minister of Environment

Type of actor	Institutional
Name	The WEEE– System
Job title of the interviewee	Office manager, Financial Co-ordinator

Industry/sector associations

Type of actor	Industry association
Organisation name	LWF
Job title of the interviewee	Office manager, Financial Coordinator

Type of actor	Industry association
Organisation name	Elretur
Job title of the interviewees	Controller

Type of actor	Industry association
Organisation name	Nera
Job title of the interviewees	WEEE-marketing Manager; R&D Manager

Type of actor	Industry association
Organisation name	RE-DK
Job title of the interviewees	Marketing Manager

Producers/importers

Type of actor	Producer
Organisation name	Bang and Olufsen
Job title of the interviewees	Consultant, Quality and Environment

Type of actor	Producer
Organisation name	Bayer
Job title of the interviewees	Manager division plastics products – Car industry

Type of actor	Producer
Organisation name	Danfoss
Job title of the interviewees	Approval Manager /WEEE project manager; Quality, Environment and Safety Manager

Type of actor	Importer - wholesaler
Organisation name	ElGiganten
Job title of the interviewees	General Director

Type of actor	Producer
Organisation name	Nokia
Job title of the interviewees	Senior Environmental Manager, CMO Sales & Marketing Europe; Product Design Manager - Denmark, Sales Manager – Sweden, Environment Consultant – Network division, Finland

Type of actor	Producer
Organisation name	Novo Nordisk
Interviewed persons title	Regulatory Affairs Consultant and Environmental Advisor

Type of actor	Producer
Organisation name	Zitech
Job title of the interviewees	Sales Manager

Waste management companies

Type of actor	Recycler
Organisation name	Stena Technoworld
Job title of the interviewees	R&D Department Manager- Business Area WEEE

Type of actor	Recycler
Organisation name	H. J. Hansen Elektromiljø
Job title of the interviewees	Marketing Manager

Case study 1 – Interviewed actors – Italy

Institutions

Type of actor	Institutional
Name of the organisation	Center of Coordination RAEE
Job title of the interviewees	General director

Industry/sector associations

Type of actor	Industry association
Name of the organisation	Ecodom
Job title of the interviewees	General Director

Importers/producers

Type of actor	Producer
Name of the organisation	Canon
Job title of the interviewees	Environmental consultant

Waste management companies

Type of actor	Recycler
Name of the organisation	Elettrorecycling
Job title of the interviewees	Business development manager

Case study 2 – Interviewed actors – Denmark

Producers/importers

Type of actor	Producer
Organisation name	ALPHABETA
Job title of the interviewees	Program Manager, ALPHABETA Integrated Supply Chain - Europe Reverse Logistics

Third party logistics providers

Type of actor	Logistics service provider
Organisation name	Geodis Asset Recovery Center- Germany
Job title of the interviewees	Senior Manager and Reverse & Spare Parts Logistics - Branch Manager

Case study 2 – Interviewed actors – Italy

Third party logistics providers

Type of actor	Logistics service provider
Organisation name	Geodis
Job title of the interviewees	Manager – Division Reverse Logistics; Lawyer

Type of actor	Logistics service provider
Organisation name	DHL
Job title of the interviewees	WEEE Business Development Manager

Appendix II: The interview guide for the different actors

The interview guide for the institutions and industry/sector associations

General information	– Institution/association name – Interviewed person – Position in the organisation – Contact information – Date of the interview
General questions	1. The role on the implementation process 2. The responsibilities in the implementation process 3.

The interview guide for the producers/importers

General information	– Company name – Interviewed person – Position in the company – Contact information – Date of the interview

General questions	1. Please provide a short history of reverse logistics in your company
	2. Please describe the return flow
	   – Items/products
	   – Information
	3. Does the return flow utilise the current supply chains or a dedicated supply chains?
	4. Please describe the reverse logistics services

Members in the reverse supply chain	1. What are the immediate suppliers and customers of returned products?
	2. Please describe the:
	   – Characteristics of customers and the return policies
	   – Characteristics of suppliers and the return policies

Product return	1. What are the reasons for accepting product return?
	   – WEEE
	   – Commercial returns
	   – Others…
	2. Does WEEE effect you company?
	3. Hoe much of the returns are caused by WEEE? (Return rates)

Reverse logistics activities	4. Please provide a description of all the major logistics activities related to reverse logistics:
	   – Transport
	   – Material handling
	   – Inspection
	   – Remanufacturing/reconditioning
	   – Recycling
	   – Disposing
	   – Distribution and sale

Competence in providing	1. Which specific know-how did your company developed in order

reverse logistics	to provide reverse logistics services?
	2. Which new knowledge did you company acquired?
	3. Which functions/units/departments have been affected the most?
Products	1. What type of products (in relation to the various RL activities) do you get back?
	– Product type
	– Status
	– Time sensitive vs. cost sensitive
	2. If any difference, please provide a description of the reverse flow for commercial versus environmental product returns
Enabling technology	1. Which information system does you company use to support the reverse logistics activities?
	2. Did your company make specific investments on IT or other facilities?
	3. Did your company make any specific investments in dedicated material handling equipment?
Future perspectives	1. What barriers did your company have to overcome to implement reverse logistics?
	2. Do you see any other current or future barrier to overcome?
	3. What are the possible Growing opportunities?
	4. What are the Existing customers and which other customers could you approach?

The interview guide for the logistics service providers

General questions	– History of RL in the company
	– Describing the return flow
	o Items/products
	o Information
General questions	1. To which extent different infrastructures and managerial tools are deployed according to the type of the service offered?
	2. Why do providers of reverse logistics services need a different set of structures to serve the need of their customers?
	3. Which synergies may be achieved if these three streams of reverse flow are combined, or cooperation is established between the business units that manage them?
In general about the function	1. What do you understand by "remanufacturing"?
	a. Volume pr. year
	b. Number of products
	c. Need for new knowledge
	d. Need for new technology
Product dimension.	1. What products do you get in (dimensions, variety, quantities)?
	2. In which status / condition? Is the product status known in advance, for instance for leased product they do)?
	– Product structure and configuration (meaning the BOM for instance, components, material and how to dismantle).
	– What items can be remanufactured.
	3. Supply of spare parts for remanufacturing purposes
	– what spare parts?
	– how is it organised?

Process – the "logistics infrastructure"	1. Inbound process: how they get the product in?
	  – What triggers the order?
	  – Do they know when and how much they receive the items?
	2. Which transportation system/consolidation system do they use and how they get the order?
	  – point of collection
	  – who collects
	  – what triggers the order for collection
	3. Internal process:
	  – What phases
	  – Any common phases
	  – Any separated steps; work in batches or product by product, in lines, in parallel, job shop concept or more line?
	  – Average time of processing, and specific times for processing
	  – Tools capacity management
	4. Outbound process: how the remarketing process evolves?
	  – Which market?
	  – Who? Retailer versus. after sale versus….
	5. Agreements with customers on service levels
	6. Flexibility of the process.
	7. Manual versus automatic materials handling systems.
	8. Local versus international customers.

Future	1. Current and / or future challenges in terms of serving:
	  – More volume
	  – More variety
	2. What are current opportunities and constrains in terms of volume, product variety, process variety and in general?

Waste management companies

General information	– Company name – Interviewed person – Position in the company – Contact information – Date of the interview
General questions	1. Which products you treat 2. How the WEEE recovery has effected your activities 3. which part of the return flow you deal with 4. Please describe the reverse logistics services that you provide, if any
Treatment process	1. What are the deployed technologies 2. Treatment capacity and capacity utilisation 3. Treated volumes and characteristics 4. Recyling rates 5. Reporting issues
The output market	1. What are the recycled fractions? (metals, plastics. etc…) 2. To whom do you sell the recycled fraction? And where your customers are located? 3. Do you have any procedures to check to downstream flow?

Appendix III: List of products which fall under each category of the WEEE Directive

1. **Large household appliances**
   – Large cooling appliances
   – Refrigerators
   – Freezers
   – Other large appliances used for refrigeration, conservation and storage of
   – food
   – Washing machines
   – Clothes dryers
   – Dish washing machines
   – Cooking
   – Electric stoves
   – Electric hot plates
   – Microwaves
   – Other large appliances used for cooking and other processing of food
   – Electric heating appliances
   – Electric radiators
   – Other large appliances for heating rooms, beds, seating furniture
   – Electric fans
   – Air conditioner appliances
   – Other fanning, exhaust ventilation and conditioning equipment

2. **Small household appliances**
   – Vacuum cleaners
   – Carpet sweepers
   – Other appliances for cleaning
   – Appliances used for sewing, knitting, weaving and other processing for textiles
   – Irons and other appliances for ironing, mangling and other care of clothing
   – Toasters
   – Fryers
   – Grinders, coffee machines and equipment for opening or sealing containers or packages
   – Electric knives
   – Appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances
   – Clocks, watches and equipment for the purpose of measuring, indicating or registering time
   – Scales

3. **IT and telecommunications equipment**
   – Centralised data processing:
   – Mainframes
   – Minicomputers
   – Printer units
   – Personal computing:
   – Personal computers (CPU, mouse, screen and keyboard included)
   – Laptop computers (CPU, mouse, screen and keyboard included)

- Notebook computers
- Notepad computers
- Printers
- Copying equipment
- Electrical and electronic typewriters
- Pocket and desk calculators and other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means
- User terminals and systems
- Facsimile
- Telex
- Telephones
- Pay telephones
- Cordless telephones
- Cellular telephones
- Answering systems and other products or equipment of transmitting sound, images or other information by telecommunications

4. Consumer equipment
- Radio sets
- Television sets
- Videocameras
- Video recorders
- Hi-fi recorders
- Audio amplifiers
- Musical instruments
- And other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications

5. Lighting equipment
- Luminaries for fluorescent lamps with the exception of luminaries in households
- Straight fluorescent lamps
- Compact fluorescent lamps
- High intensity discharge lamps, including pressure sodium lamps and metal halide lamps
- Low pressure sodium lamps
- Other lighting or equipment for the purpose of spreading or controlling light with the exception of filament bulbs

6. Electrical and electronic tools (with the exception of largescale stationary industrial tools)
- Drills
- Saws
- Sewing machines
- Equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending or similar processing of wood, metal and other materials
- Tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses
- Tools for welding, soldering or similar use
- Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means
- Tools for mowing or other gardening activities

7. Toys, leisure and sports equipment
- Electric trains or car racing sets
- Hand-held video game consoles
- Video games
- Computers for biking, diving, running, rowing, etc.
- Sports equipment with electric or electronic components
- Coin slot machines

8. Medical devices (with the exception of all implanted and infected products)
- Radiotherapy equipment
- Cardiology
- Dialysis
- Pulmonary ventilators
- Nuclear medicine
- Laboratory equipment for *in-vitro* diagnosis
- Analysers
- Freezers
- Fertilization tests
- Other appliances for detecting, preventing, monitoring, treating, alleviating illness, injury or disability

9. Monitoring and control instruments
- Smoke detector
- Heating regulators
- Thermostats
- Measuring, weighing or adjusting appliances for household or as laboratory equipment
- Other monitoring and control instruments used in industrial installations (e.g. in control panels)

10. Automatic dispensers
- Automatic dispensers for hot drinks
- Automatic dispensers for hot or cold bottles or cans
- Automatic dispensers for solid products
- Automatic dispensers for money
- All appliances which deliver automatically all kind of products

Appendix IV: WEEE data reported to the Minister of Environment (Denmark 2006)

Dette dokument giver en oversigt over de mængdedata, som producenterne har rapporteret til WEEE-System for 2006. Der var med udgangen af 2006 foretaget 992 virksomheds registreringer. Data som er præsenteret her, er trukket ud af WEEE-Systems database den 06.06.07.

Tabel 1 og 2 giver en oversigt over de, af producenterne rapporterede mængder, som er markedsført.

Tabel 2 giver en oversigt over de mængder der er tilbagetaget som el-skrot. Størstedelen af dette el-skrot må antages at være historisk el-skrot, hvilket vil sige at produkterne blev solgt før producentansvaret trådte i kraft 1. april 2006. Tabel 3 giver et overblik over hvor el-skrottet får sin første behandling. Tabel 4 giver et overblik over i hvor høj grad producenterne, som helhed, lever op til WEEE direktivets målsætninger for nyttiggørelse, genbrug og genanvendelse. Det ses af tabel 1, at der er markedsføreres 3 gange så stor en mængde elektronik produkter til husholdninger som til erhverv.

Af de totale markedsførte mængder stammer 48 % fra kategori 1. Alene husholdningsdelen af kategori 1 udgør 44 % af de totalt markedsførte mængder.

Den næststørste kategori er kategori 3 med 19 % af de markedsførte mængder. For kategori 3 er erhvervsdelen næsten dobbelt så stor som husholdningsdelen.

Kategori 4 er den tredjestørste kategori på 15 %, som stort set alene stammer fra markedsføring til husholdninger. Kategori 2 og 6 er på henholdsvis 6 % og 5 % af de markedsførte mængder. De resterende 7 % udgøres af kategori 5, 7, 8, 9 og 10 tilsammen. Hver af kategorierne 5, 5a, 8, 9 og 10 udgøres næsten totalt (%-andel 99 %) af markedsføring til erhverv.

I 2006 var der ca. 5.430.000 millioner indbyggere i Danmark. Det betyder, at der af de registrerede producenter blev markedsført 39 kg elektriske og elektroniske produkter per indbygger i Danmark. De 30 kg per indbygger blev markedsført til husholdninger og de 9 kg per indbygger blev markedsført til erhvervsvirksomheder. Af tabel 2 ses det, at der i alt blev indsamlet 57.881 tons el-skrot i henhold til reglerne om producentansvar. Af det indsamlede el-skrot stammer 94 % fra private husholdninger og de resterende 6 % fra erhverv. Kun kategori 5 *lyskilder og armaturer*, og kategori 10 *salgsautomater* har en større indsamling fra erhverv end fra husholdninger. For armaturer skyldes det, at der ikke er producent-ansvar for armaturer solgt til husholdninger. For salgsautomater skyldes det, at disse ikke markedsføres til husholdningsbrug.

Interessant nok er kategori 7 *legetøj, fritid og sportsudstyr*, den eneste kategori, der har en væsentlig andel af det indsamlede el-skrot fra erhverv.

De mængdemæssigt største kategorier er kategori 1 med 51 %. Dernæst kategori 4 med 24 % af det indsamlede el-skrot og kategori 3, som repræsenterer 20 % af det indsamlede el-skrot.

Kategorierne 2, 6, 7, 8, 9, som udgør genbrugspladsernes indsamling af husholdningernes el-skrot fraktion 2, udgør 4 % af det indsamlede el-skrot. Den sidste 1 % af de tilbagetagede mængder udgøres af kategori 5 og 10 tilsammen.

Sammenlignes tabel 1 og tabel 2, hvor det i tabel 1 blev fundet at hver af kategorierne 5, 5a, 8, 9 og 10 udgøres næsten totalt (%-andel 99 %) af markedsføring til erhverv (tabel 1), ses det at denne trend ikke går igen ved indsamlingen af el-skrot (tabel 2) for kategori 5a, 8, 9. I den forbindelse skal det bemærkes, at de kollektive ordninger har lavet en teknisk beregning af fraktion 2s sammensætning for husholdnings el-skrot på kategorierne 2, 6, 7, 8, 9.

Der blev totalt set indsamlet 10,7 kg el-skrot per indbygger i Danmark i henhold til reglerne om producentansvar. Heraf er de 0,7 kg per indbygger fra erhverv og de 10 kg fra husholdninger. Efterhånden som de erhvervsprodukter, som blev solgt før 1. april 2006 forsvinder, bliver der større mængder af el-skrot fra erhverv, som også er omfattet af producentansvar. Derfor er det forventningen, at andelen af erhvervs el-skrot, som bliver rapporteret indsamlet via producentansvar, vil stige fremover.

Målsætning i EU for indsamling af el-skrot via producentansvar er 4 kg per indbygger, svarende til 21.500 tons. Hvilket betyder at Danmark klart opfylder denne målsætning.

Af tabel 3 fremgår det, at der i 2006 i alt blev behandlet 56.121 tons el-skrot i henhold til reglerne om producentansvar. Heraf blev de 67 % af el-skrottet i første omgang behandlet i Danmark, og de 33 % af el-skrottet fik deres første behandling i et andet EU land. Intet el-skrot blev sendt til behandling på anlæg i lande uden for EU.
At 2/3-dele af el-skrottet i første omgang behandles i Danmark, betyder ikke, at det også finder sin fremtidige anvendelse i Danmark.

Sammenholdes total tallene fra tabel 2 og 3 kan man se, at 97 % af det, i 2006, indsamlede el-skrot også blev behandlet i 2006.

Tabel 4 viser en oversigt over, hvor meget af det indsamlede el-skrot, som er bortskaffet, hvilket i Danmark typisk er deponering. Herefter ses en oversigt over, hvad der er nyttiggjort, sammenholdt med EU målsætningerne for nyttiggørelse. Tilsvarende vises en oversigt over hvor meget der er sendt til genbrug og genanvendelse, sammenholdt med EU målsætningerne for genbrug og genanvendelse.

Bemærk definitionerne af bortskaffelse, nyttiggørelse, genbrug og genanvendelse:

- Bortskaffelse: En af de processer, der er nævnt i Elskrotbekendtgørelsens bilag 5.

- Nyttiggørelse: En af de processer, der er nævnt i Elskrotbekendtgørelsens bilag 6.

- Genbrug: Enhver proces, hvorved affald af elektrisk og elektronisk udstyr (WEEE) eller komponenter herfra eller affald af andet elektrisk og elektronisk udstyr eller komponenter herfra fortsat anvendes til samme formål, som de blev fremstillet til, og som returneres til indsamlingssteder, distributører, genvindingsvirksomheder eller fabrikanter.

- Genanvendelse: Oparbejdning i en produktionsproces af affaldsmaterialer til deres oprindelige formål eller andre formål bortset fra energiudnyttelse, hvorved

menes anvendelse af brændbart affald som et middel til energifremstilling gennem direkte forbrænding med eller uden andet affald, men med udnyttelse af varmen.

Genbrugs- eller genanvendelsesandelen opgøres på grundlag af den modtagne tonnage affald pr.

kalenderår og andelen heraf, der efter særskilt behandling, jf. § 21, er leveret til genbrug eller genanvendelse. Nyttiggørelsesandelen opgøres på grundlag af den modtagne tonnage affald pr. kalenderår, og den andel heraf, der efter særskilt behandling, jf. § 21, er leveret til nyttiggørelse.

Det ses af tabellen, at Danmark lever op til EU målsætningerne.

Tabel 1 Markedsførte EEE produkter i 2006

År 2006 - tons	Realiserede tal - Husholdninger	Realiserede tal - Erhverv	Realiserede tal - Total*
1) Store husholdningsapparater	76.819	6.741	83.560
2) Små husholdningsapparater	10.185	1.031	11.216
3) It- og teleudstyr	12.654	21.051	33.705
4) Forbrugerudstyr	24.436	1.144	25.580
5) Belysningsudstyr - armaturer	0	4.783	4.783
5) Belysningsudstyr - lyskilder	234	1.999	2.233
6) Elektrisk og elektronisk værktøj	6.554	2.620	9.174
7) Legetøj, fritids- og sports udstyr	1.751	327	2.078
8) Medicinsk udstyr	65	1.783	1.848
9)Overvågnings- og reg. instrum.	41	1.328	1.369
10) Salgsautomater	0	343	343
Total	132.739	43.150	175.889

Note: * kun realiserede mængder. Dvs. ingen budgetterede mængder for markedsføring.

Tabel 2 Tilbagetaget WEEE i 2006

År 2006 - tons	Indsamlet fra husholdninger	Indsamlet fra andre end husholdninger	Total WEEE indsamlet
1) Store husholdningsapparater	28.327	1.388	29.715
2) Små husholdningsapparater	1.198	34	1.232
3) It- og teleudstyr	10.051	1.314	11.365
4) Forbrugerudstyr	13.594	218	13.812
5) Belysningsudstyr - armaturer	0	113	113
5) Belysningsudstyr - lyskilder	211	338	549
6) Elektrisk og elektronisk værktøj	521	31	552
7) Legetøj, fritids- og sports udstyr	250	109	359
8) Medicinsk udstyr	37	8	45
9)Overvågnings- og reg. instrum.	81	3	84
10) Salgsautomater	0	55	55
Total	54.270	3.611	57.881

Note: Indsamlingen af el-skrot fra husholdninger foregår i fem fraktioner, hvor fraktion 2 består af kategori 2, 6, 7, 8, 9. De resterende fraktioner 1, 3, 4 og 5 har numre som er overensstemmende med kategorinumrene.

3 Geografisk område for behandling af el-skrot

År 2006 - tons	Behandlet I Danmark	Behandlet I andre EU stater	Behandlet uden for EU
1) Store husholdningsapparater	16.996	10.696	0
2) Små husholdningsapparater	1.225	174	0
3) It- og teleudstyr	8.236	3.832	0
4) Forbrugerudstyr	9.857	3.387	0
5) Belysningsudstyr - armaturer	114	2	0
5) Belysningsudstyr - lyskilder	269	155	0
6) Elektrisk og elektronisk værktøj	599	75	0
7) Legetøj, fritids- og sports udstyr	258	30	0
8) Medicinsk udstyr	55	6	0
9) Overvågnings- og reg. instrum.	90	10	0
10) Salgsautomater	55	0	0
Total	37.754	18.367	0

Note: I denne tabel er der ikke skelnet mellem hvorvidt det behandlede el-skrot kommer fra husholdning eller erhverv. Skemaet viser den samlede håndtering af el-skrot.

Tabel 4 EU målsætninger for genbrug og genanvendelse

År 2006	B	B%	N	N%	EU mål N	G	G%	EU mål G
1) Store husholdningsapparater	959	3%	26.733	97%	80%	24.445	88%	75%
2) Små husholdningsapparater	61	4%	1.338	96%	70%	1.144	82%	50%
3) It- og teleudstyr	1.002	8%	11.066	92%	75%	9.823	81%	65%
4) Forbrugerudstyr	1.238	9%	12.016	91%	75%	10.468	79%	65%
5) Belysningsudstyr - armaturer	17	15%	99	85%	70%	99	85%	50%
5) Belysningsudstyr - lyskilder	10	2%	414	98%	80%	414	98%	50%
6) Elektrisk og elektronisk værktøj	26	4%	648	96%	70%	552	82%	50%
7) Legetøj, fritids- og sports udstyr	10	4%	277	96%	70%	234	81%	50%
8) Medicinsk udstyr	3	5%	58	95%	70%	49	80%	50%
9)Overvågnings- og reg. instrum.	4	4%	96	96%	70%	81	81%	50%
10) Salgsautomater	2	4%	53	96%	80%	44	80%	75%
Total	3.332			52.798			47.353	

Note: I denne tabel er der ikke skelnet mellem hvorvidt det indsamlede el-skrot kommer fra husholdning eller erhverv. Skemaet viser den samlede håndtering af el-skrot.

B: Bortskaffelse Ton
N: Nyttiggørelse Ton
G: Genbrug og genanvendelse Ton