THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Product Recovery in Business Networks: An Inter-organisational Approach

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ABSTRACT

This doctoral dissertation analyses various ways of organising product recovery in inter-organisational networks. The purpose of product recovery is to dispose products in an environmentally responsible manner, which is strongly associated with the conservation of raw materials and sustainability. The aims of the thesis are (i) to develop a theoretical framework for organising of product recovery since this has been asked for in previous research, and (ii) to apply this framework in an empirical study.

The framework is based on the Industrial Network Approach, with its three basic pillars: actors, activities and resources. In this way the study complements the previous research focus on activities with analysis of resources and actors.

The empirical context of the thesis includes two qualitative case studies in the PC industry. The first case takes the starting point in a firm involved in coordination of product recovery networks, while the second centres on a disposer of used PCs.

The study shows that the most significant issues in the organizing of product recovery are concerned with the coordination of interdependent activities and the combining of physical and organizational resources. Effective organizing in these respects is contingent on interaction and information exchange among actors. In these processes joint classification systems and sorting rules are crucial in order to maintain and enforce routines in the product recovery operations from disposer to end user.

Regarding implications for practice the study shows that the organising of product recovery is affected by substantial uncertainties with regard to supply and demand. These problems can be handled through increasing collaboration between the business partners in the recovery network, which provides opportunities for enhanced economies of scale, and joint planning of collection, transportation and reprocessing.

Key words: *Product recovery, sustainability, organising, reverse logistics, Closed Loop Supply Chain Management, industrial network, business network, classification systems, transvection.*

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I want to thank the members of my family for their love, encouragement, patience, assistance, and support. Finally, my thanks go to the members of the 'Great Society', and its institutions for their vital help and love.

> *'In civilised society he stands at all times in need of the*
> *cooperation and assistance of great multitudes,while*
> *his whole life is scarce sufficient to gain the*
> *friendship of a few persons.'* (Smith, 1776, p. 14)

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Igor Insanic

Göteborg, November 2014

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1 INTRODUCTION

In this chapter, the background and the research area of the study – that is, product recovery – are presented with respect to their theoretical and practical significance. A discussion on the importance of taking a relational and network perspective on organising product recovery in this study outlines the aim of the thesis. Finally, this introductory chapter concludes with a presentation of the structure of the thesis, in order to provide the reader with an overview of, and guide to, this thesis.

1.1 Background

This thesis deals with organising product recovery in general, and in the PC industry in particular. Product recovery is mainly related to the sustainable recovery and decrease of material resources. The most common definition of sustainability is the use of resources to meet the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). The three dimensions of sustainable development, *economy, environment and society*, constitute a framework, within which economic growth goes hand in hand with environmental and social awareness (de Brito et al., 2008; Winkler, 2011; Ye et al., 2013). This awareness of environmental aspects and ecological sanctions began to become prominent in the 1960s, as reported by Alderson and Green (1964), who addressed this topic by linking identity and survival to the concern for conservation of natural resources, which in turn constitute constraints on the managers. Hence, Alderson and Green, and Ye et al. (2013) invited managers to make their own rules, apart from those imposed by the authorities under the pressure of ecological sanctions. Since the beginning of the 1990s, these concerns, in combination with recycling regulations, confront managers with increasing pressure to '*dispose of products in an environmentally responsible manner*' (Ilgin and Gupta, 2010, p. 563).

The framework of sustainable development emphasises the need for the recovery of products, by-products, and waste during production, distribution, use, and after use,[1] which all improve resource utilisation (Um et al., 2008). Reuse, resale, repair, refurbishing, remanufacturing, and recycling are examples of product recovery activities. By recovering consumed raw materials and returning them to the business systems and supply chains, and/or by decreasing material resource consumption within these settings, firms can improve the sustainability of their business (Lebreton, 2006; Keyvanshokooh et al., 2013; Krikke et al., 2013). Typical examples of products that have been recovered for centuries are high-value and low-volume items, such as locomotive engines (Guide and van Wassenhove, 2009). Especially during and after the Second World War, product recovery experienced a boom (Sundin, 2006). This was caused

[1] Product life is defined as the progress of a product from raw materials to the final end product.

by the lack of many raw materials needed for manufacturing. The increasing scarcity of resources is making the environmentally sound reuse of natural resources more economically profitable (Porter and van der Linde, 1995; Romm, 1999; Flapper et al., 2005; Francas and Minner, 2009; Winkler, 2011). In fact, already back in 2007, approximately 40 per cent of the global steel production, and 50 per cent of the paper production, originated from the recycling of these materials (Stena Metall, 2007). Guide and van Wassenhove (2009) argued that current real examples, such as non-subsidised and/or not legislatively enforced remanufacturing, highlight the profitability of product recovery processes.

A category of products that is frequently recovered in business networks is commercial returns, with estimated annual costs of $100 billion in the United States as far back as 2002 (Stock et al., 2002). Home Depot, for example, experiences commercial return rates of 10 per cent of total sales, or higher (Guide and van Wassenhove, 2009). PC assemblers have short life-cycle products that can lose 1 per cent of their value per week, and also have high return rates (Guide et al., 2006). These product classes, as well as closeouts and unsold stock items, represent an important potential for value recovery.

The reused resources may be whole products, parts, materials, energy, labour, and other assets that have been consumed during the production, distribution and use of new products (Östlin et al., 2009). In most cases, transportation does not represent the main share of the total environmental impact of a product during its whole life, since the environmental costs of production are normally higher (Clift, 2003; Abrahamsson, 2009). From an ecological perspective, it is furthermore essential to reflect on the life extension of items that incur their major environmental impact during the use phase (Bras and McIntosh, 1999), such as remanufactured fossil fuel engines that are not as environmentally friendly as newly manufactured ones, or renewable fuel engines. However, in the computer industry and in the brown goods[2] industry in general, resource consumption during use is lower than during the stages of extraction and production (Grote, 1994).

In addition, in 1999 electric and electronic waste represented the fastest increasing waste stream in Europe, growing at an annual rate of 3–5 per cent, which was three times faster than the average increase in waste (Thomas et al., 1999). One of the reasons for this was a shortening of the sales life cycles[3]. As a consequence, environmental laws have been passed that provide for producers paying fees for the recycling and disposal of electric and electronic

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[2] Electronic products such as computers, printers, and servers.

[3] The sales life cycle is defined as the progress of a product through the stages of introduction, growth, maturity and decline of sales (Cox, 1967). This life cycle also affects recovery decisions in case the product that is about to be refurbished is declining in sales. This, in turn, could mean that a product needs to be upgraded with new components and that a once-standardised product may, after use, become a customised one, or vice versa if the upgrade does not take place.

waste. Thus, the increasing cost of the disposal of hazardous waste and recycling might become a supplementary motive to initiate other recovery processes of products that come from different stages and actors during the life of a product. This is often more economically feasible than the passive financing of collection and recycling firms (Lebreton, 2006).

Stock (1998) stated that the shift from selling products to selling sets of services (for example, leasing), makes use, repair and recovery of materials, parts, and products more desirable and profitable to manage. When, in this way, a manufacturer attains a larger degree of control of the product throughout the value chain, it becomes easier to secure the supply and timing of the product flow aimed towards recovery activities (Thierry et al., 1995; Defee et al., 2009; Faccio et al., 2014).

Two customer-demand trends recognised by computer manufacturers are shrinking IT budgets and the increased rationality of users who cannot afford new computers or do not consider it necessary to keep pace with every innovation cycle (Lebreton, 2006). That is why many computer manufacturers now also offer refurbished computers. Increasing the environmental awareness of the population is also creating opportunities for marketing the recovered goods (Stock, 1998).

To summarise, there are certain increasingly important aspects of the present business environment that contribute to the promotion of product recovery as an environmentally preferable alternative to disposal, within both the business and policy communities. The first aspect is the ambition to diminish the environmental impact from firms in terms of waste reduction. Another important issue is the cost minimisation of product recovery processes and the resources employed in these activities. Aronsson and Huge-Brodin (2006) emphasised that logistics costs and environmental impact often point in the same direction; thus, a solution that lowers the cost of transportation almost always reduces pollution as well. Legislative requirements to decrease the amount of hazardous waste disposed in landfills are forcing companies to commit resources to product recovery in terms of design for the ease of disassembly and recycling. Several needs and requirements of the business and private consumers with regard to the lack of virgin raw materials and awareness of ecological sustainability may also be factors that can turn product recovery into a source of profits and competitive advantage (Porter and van der Linde, 1995; van Hoek, 1999; Kocabasuglo et al., 2007; Ye et al., 2013). All in all, product recovery research has practical importance for several stakeholders in society. This practical side of the topic, and its theoretical importance, are outlined below.

1.2 Importance of product recovery and positioning of the study

Product recovery research started in the 1970s with reverse distribution literature (e.g., Zikmund and Stanton, 1971; Guiltinan and Nwokoye, 1975; Ginter and Starling, 1978). Until the mid-1990s, this research dealt mainly with the operational processes of recycling collected ‘end-of-life’ products from end users to reprocessing facilities. During the 1990s, product recovery research broadened its field to include other reprocessing activities, such as refurbishing. The trend of including other organisational and managerial disciplines, such as marketing and inter-organisational issues in the 2000s, evolved into the Closed Loop Supply Chain Management research, which includes waste and other by-products from several supply sources during production, distribution and use (Guide and van Wassenhove, 2009).

Reverse logistics literature has mainly focused on the efficiency, organisation, planning and effectiveness of coordination processes for financial, informational and physical flows in the reverse supply chain. These issues are enforced by legislation imposing producer responsibility for electronic waste, and are established with the cooperation of the Original Equipment Manufacturers (e.g. Jahre, 1995; Flygansvaer, 2006; Grunow and Gobbi, 2009). This type of research within the product recovery area is concerned with businesses and/or individual end-consumers as suppliers of the end-of-life products, and how to organise logistics set-ups in order to increase collection rates (Jahre, 1995). This goal is to be achieved by organising and providing various logistics solutions to the disposers.

The overall ambition of this thesis is to explore organising issues in product recovery. The next two sections will cover the organising issues both from a single firm’s perspective and in an inter-organisational sense in order to mark off the delimitations of the study.

1.2.1 Organisational aspects in product recovery

Reverse logistics literature has identified several organisational challenges that need to be addressed in studies dealing with product recovery, with the most important of these being the uncertainty of supply in terms of lack and complexity of information about the inputs to reprocessing (e.g. Fleischmann et al., 2001; Flygansvaer, 2006; Defee et al., 2009). Toffel (2004) discussed the lack and abundance of information attributed to supply uncertainty as factors that can reduce efficiency of product recovery. Uncertain information on timing, quantity, demand, and material properties creates highly variable processing times. Furthermore, supply uncertainty diminishes the ability to achieve economies of scale in routings of materials for repair and remanufacturing. These uncertainties call for a higher degree of coordination of information in the reverse logistics networks (Lambert and Stock, 1993; Jahre, 1995; Fleischmann et al., 1997, 2000; Blumberg, 1999; Krikke et al., 1999a, 1999b; Yalabik et al., 2005; Das and Dutta, 2013). Therefore, prediction, appropriate structuring and control of the information about matching the demand with returns is a key success factor for profitable product recovery (Toffel, 2004; Listes and Dekker, 2005; Krapp et al., 2013). The lack of organisation and coordination in collection and transportation creates a large number of low-volume physical flows, which is both a costly and environmentally unsound practice (Fleischmann et al., 2001; Flygansvaer, 2006; Faccio et al., 2014).

The focus of reverse logistics research is frequently on the supply side, in terms of describing, classifying, and explaining efficient systems for the collection, distribution, and reprocessing of products at the end of life. The point of departure in this study is based on the fact that there is a need to go beyond the supply side of the reprocessing phase. In this thesis, the end user of a remanufactured or recycled product is therefore considered part of a recovery network of interlinked organisations.

Effectively matching supply of returns and users' demand is the most essential challenge in Closed Loop Supply Chain Management (Fleischmann et al., 2000; Toffel, 2004), as in other areas of Supply Chain Management. Thus, Krikke et al. (2004) added distribution to the secondary end user, as an additional activity, in their framework of reverse logistics. Fleischmann (2001, p. 19) argued that *'both at the front and the back-end the actual* "*reverse*" *network is linked with other logistics structures that one would typically consider as* "*forward*" *networks.'* According to Winkler (2011), product recovery configurations should not be perceived as isolated objects, but rather as part of some larger overall logistics structure. The importance of reverse physical flows is visible in the framing of the total logistics system by the Council of Supply Chain Management Professionals, which defines *logistics system*s as those that facilitate *'the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements'* (Council of Supply Chain Management Professionals, 2010).

From an historical perspective, reverse logistics literature was a forerunner of the Closed Loop Supply Chain Management research (Guide et al., 2003), which started to develop in the 1990s thanks to the research conducted on remanufacturing of fighter jets and Xerox photocopiers. A pioneering group of operations and production-management researchers was mostly interested in the technical intra-firm recovery perspective. Their essays acknowledged uncertainties in the supply of form, quality, quantity and time across several parts of these networks, and scrutinised the interaction between product design, production and inventory management of new and reused parts and products in Closed Loop Supply Chains (e.g., Thierry et al., 1995; Lund, 1984, 1996; van der Laan et al., 1999; Ferrer and Whybark, 2001; Guide and van Wassenhove, 2002; Sundin, 2004; Defee et al., 2009). An additional research area within the product recovery field, called Environmentally Conscious Manufacturing and Product Recovery, which deals with the integrated aspects of forward and reverse supply chains was reviewed by Ilgin and Gupta (2010). The scholars' reasoning with respect to this research field is similar to that of researchers working within Closed Loop Supply Chain management, who argue that there is a need for more coordinated approaches across reverse and forward supply chains. However, most scholars conducting research on product recovery have focused on dyads or supply chains from the viewpoint of a focal firm (Cheng and Lee, 2010; Lee and Lam, 2012).

Business issues such as marketing (Jacobsson, 2000) were discussed in the early strategic product recovery literature. Jacobsson's (2000) results, which were later confirmed by Sundin (2004), indicate that an Original Equipment Manufacturer may experience several benefits when providing a leased product with maintenance and repair services. This arrangement reduces the supply uncertainty and ensures consistency in the quality of products/parts during the product's life, as well as a sufficient volume flow of goods for product recovery to be economically feasible. A number of researchers (Fleischmann et al., 2001; White et al., 2003; Flapper et al., 2005; Lebreton, 2006; Salema et al., 2010) have recognised the synergy effects of shared facilities, and decreased economic and environmental impact as a result of the consolidation of distribution of new products with the collection of end-of-lease goods.

During the first decade of the twenty-first century, many researchers within the product recovery field showed a growing interest in business management and organisational issues, such as strategy, organisational behaviour, supply chain management, marketing, and the competitive advantage approach (Thierry et al., 1995; Jacobsson, 2000; Flapper et al., 2005; Lebreton, 2006). However, this more business-oriented product recovery management research has not yet reached its full potential. Sharma et al. (2010) listed 33 articles about sustainable marketing and identified only six that in some way deal with business marketing and purchasing, arguing that marketing has been mainly concerned with targeting customer segments for new green products, and that very little attention has been given to business marketing and purchasing in a green supply chain, and its interface with environmentally friendly manufacturing, reprocessing, distribution and other operations.

Identifying the need for more research on multi-agent networks, Srivastava (2007) stated that distribution networks of recovered products have evolved and become more differentiated as they now involve not only brokers, but also online and traditional auctions. Despite the fact that Tibben-Lembke (2004) explained that secondary markets provide an opportunity for sales expansion, Guide and van Wassenhove (2009, p. 16) asked for more business-management-orientated research within product recovery, arguing that closed loop supply chain management '*has begun to link other disciplines (i.e., marketing and accounting) to the OM*[4] *perspective. If prices and markets are not fully understood, they become barriers, no matter how well the operational system is designed. A thorough understanding clearly requires an interdisciplinary approach.*' One literature review (Govindan et al., 2014) that outlined a research direction dealing with the selection of product recovery partners by Original Equipment Manufacturers stated that cooperation between the actors influences pricing and the physical flows in a product recovery network.

[4] Operations Management.

The broadening of the focus of product recovery research in the late 2000s into the business management field was explained by the general lack of interest in Closed Loop Supply Chain Management amongst marketing and accounting research communities (Guide and van Wassenhove, 2009). This was, and remains, one of the main reasons for the shift towards the organisational orientation within this traditionally operations- and production-oriented product recovery research community. However, according to a review of reverse logistics research from a strategic perspective (Sheriff et al., 2012), there is a need to include both secondary use and remarketing and redistribution in a real scenario in future research. In addition, the rationale for the shift towards a business management approach has also been driven by relatively high remanufacturing rates for some types of refurbishing/remanufacturing segments that account for approximately 20–30 per cent or more of total consumption.[5] These rates exclude the markets for recycled, used, overstocked or repaired products. Furthermore, in 1996, the independent remanufacturing[6] sector in the United States, outside of the legally regulated sector, employed 480,000 people and had an annual turnover of $53 billion, which was comparable to these figures of each of pharmaceutical, computer, steel products, and consumer durables (appliances) sectors. Yet only the consumer durables sector already employed as many people in 1996 (Lund, 1996).[7] These numbers indicate that remanufacturing was already a significant industrial sector in the mid 1990s.

In line with the new business management orientation of the product recovery research, Lebreton (2006) used Porter’s value system (1985) in order to explain when an Original Equipment Manufacturer should engage in closed loop supply chain management, and concluded that the reasons include increasing waste management fees, high volumes of goods, or a large number of independent companies already in the recovery or second-hand market. He took a large tyre manufacturer as an example of how an Original Equipment Manufacturer acquired two large tyre-rethreading companies in the United States and European markets. Souza and D’Agosto (2013) took the perspective of a tyre reprocessor in their value chain analysis of various uses of scrap tires. Jacobsson (2000) and Flapper et al. (2005) described that the initial perspective of the majority of Original Equipment Manufacturers is that product recovery, in terms of some types of reuse,[8] will necessarily entail cannibalisation of the sales of new products. Nevertheless, there are some indications in research conducted by Ferguson and Toktay (2006) that since the reused/refurbished products are usually associated with lower prices, these products could be used to compete with the new low-quality/low-

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[5] For example, photocopiers, truck and aeroplane tyres, and auto parts (Lebreton, 2006).

[6] Without taking into account other recovery options.

[7] The US pharmaceutical, computer and steel industries employed 200,000 to 300,000 people each. The petroleum refining industry shipped twice as much value in terms of sales, but employed only one-sixth the number of people.

[8] Recycling and incineration, for instance, mean that a product loses its original identity.

price copies or independently reconditioned products. Low price in combination with warranties on refurbished products could, in turn, also increase sales volumes and market shares for the Original Equipment Manufacturers, especially in developing countries (Fleischmann et al., 2001; Lebreton, 2006). Other Original Equipment Manufacturers have chosen to internalise product recovery options to a large extent in order to attain a market share of the used products, whenever independent actors might find it profitable to engage in these kinds of activities (for example, vehicle, photocopier, and printer toner industries) (Majumder and Groenvelt, 2001).

Within the inter-organisational research area, the understanding of competition between the primary and secondary markets, and in the market for used products, has been evolving in recent years (Srivastava, 2008; Sheriff et al., 2012; Chen and Chang, 2012; Chen, 2014). Competition is one type of inter-organisational behaviour discussed in the following section, which focuses, among other things, on inter-firm interaction repertoires.

1.2.2 Inter-organisational issues in product recovery

Thierry et al. (1995) showed how Xerox saved money through well-developed product recovery strategies. Their and Srivastava's (2008) conclusion was that in order to be successful in product recovery, companies should work with suppliers on the durability of products, and design for disassembly and reprocessing,[9] which includes component/material standardisation across present and future product lines and industries. These efforts, in turn, make assembly,[10] maintenance, and repair more efficient and easy to perform. This standardisation also reduces the complexity and abundance of information, which makes the recovery process more efficient. According to Thierry et al. (1995), product recovery is usually associated with a reduced number of original vendors and decreased materials- and parts-purchasing costs. Proliferation of the assortment and differentiation of products, which are considered by Original Equipment Manufacturers to be one of the sources of competitive advantage in forward physical flows, can offset the standardisation trend and increase the costs of reverse physical flows (Huang and Su, 2013).

While most of the product recovery, reverse logistics, and Closed Loop Supply Chain Management literature has been concerned with Original Equipment Manufacturers, Lund (1996) considered the viewpoint of independent remanufacturing firms, and their technical or supply challenges. He argued that as competition increases and the remanufacturing firms gain shares in the market for used items, Original Equipment Manufacturers will use various strategies to increase the competitors' costs, such as making it difficult for the

[9] For instance, usage of the same standardised, easy-to-recycle, plastics within the automotive industry to avoid different process requirements of various kinds of plastics.

[10] Economies of scale, if standardised parts or modules can be used across future and present product lines.

remanufacturing firms to dismantle products or obtain used products. However, Chen and Chang (2012) stated that when the new and the used products have a low substitutability level, an Original Equipment Manufacturer should let a third party remanufacture the used products. According to Chen (2014), the dynamics of cooperation and competition in remanufacturing depend on the intensity of competition between remanufactured and new products, the potential size of the market for new products, manufacturing and remanufacturing costs of the Original Equipment Manufacturer and its partners, and the remanufacturing cost of the independent reprocessor.

Majumder and Groenvelt, (2001) argued that competition with remanufacturers practically forces the Original Equipment Manufacturers into the market for used goods. This competition produces environmental benefits as the Original Equipment Manufacturers can prolong the durability and design of the product in order to make a profit over multiple product life cycles. This goes hand in hand with the reasoning that product design and the forward supply chain should be considered elements of a total network (Seitz and Peattie, 2004; Winkler, 2011)

Dyadic relationships in product recovery

A number of articles (e.g., Östlin, 2005; Östlin et al., 2008; Östlin et al., 2009) have taken the perspective of the Original Equipment Manufacturers and remanufacturing firms. However, the main focus has been on how a manufacturer or remanufacturer should make decisions concerning their own activities in dyadic relationships. The focus on dyads and strategic outsourcing of reverse logistics is the main topic considered by Ko and Evans (2007), Cheng and Lee (2010), Govindan et al. (2012), Giovanni and Zaccour (2014), and Guarnieri et al. (2014). Cheng and Lee applied the Resource Based View to analyse outsourcing of reverse logistics to the third party logistics providers. The authors acknowledged the benefits arising from specialisation of actors in reverse logistics with regard to operational and environmental performance.

As noted above, most of the research and frameworks on product recovery have dealt with dyads (e.g., Ko and Evans, 2007; Östlin et al., 2008; Cheng and Lee, 2010; Giovanni and Zaccour, 2014), single reprocessing options or a single source (usually end user) of products to be recovered from a single company's point of view. These studies have mainly been conducted from the manufacturing/reprocessing or supply perspective, as Srivastava (2008, p. 319) concluded: '*We deal with supply side (returns) and returns' disposition but do not consider the coordination of the two markets. We still follow a "push" system where the volumes of returns drive the decisions and do not consider controlling product returns.'* Some notable exceptions take demand into consideration, such as Tibben-Lembke (2004), Salema et al. (2010) Rastogi et al. (2011) and Insanic (2012). Very little research with a focus on business relationships or inter-organisational issues has been conducted on the reverse side, and there has been even less on closed loop processes and inter-firm topics, although

Fleischmann et al. (2000, 2001) stressed the need for research on business relationships within the product recovery area at the beginning of the 2000s.

The most notable exceptions are studies by Choi et al. (2013), Krikke et al. (2013), Wikner and Tang (2008), Östlin et al. (2008, 2009), Östlin (2005), and Flapper et al. (2005). Their work establishes initial building blocks in grounding product recovery within inter-organisational Supply Chain Management. Two articles (Östlin, 2005; Östlin et al., 2009) have identified product acquisition techniques and classified dyads between disposers and other suppliers of used items, independent remanufacturers, third-party remanufacturers, and Original Equipment Manufacturers. These essays discuss reverse supply chain control and how uncertainty of product recovery and reverse logistics structures are handled. Other notable articles that discuss these issues, as well as collaboration contracts, quantity discounts and revenue sharing between actors in reverse supply chains, are Shi and Bian (2011) and Yi and Wang (2011).

Business relationships in closed loop supply chains

Toffel (2004) analysed the connection between uncertainties and different dyadic inter-firm setups using both the Resource Based View and Transaction Cost Economics, and argued that there is a need for more inter-organisationally focused studies within the predominantly operations-oriented research field of product recovery and reverse logistics.

Without information sharing on physical flows between organisations involved in product recovery, the lack or abundance of information creates a greater need for inventories at each step where evaluation, testing and grading need to be performed (White et al., 2003). This increases inventory and transportation costs (and thus environmental impact) if the large numbers of low-volume physical flows are not coordinated, or if a product is unnecessarily transported to an inappropriate facility (Lee and Lam, 2012). Krikke et al. (2013) stated that a critical mass of product returns has to be achieved in order for the product recovery activities to be profitable.

Srivastava (2007) wrote in the conclusion of his literature review on green supply chain management that more research is needed to create integrative frameworks in order to analyse secondary markets[11] and the whole Closed Loop Supply Chain. This would include the effects of design and the installation of sensors that can transmit information about the overall status and age of the product with regard to sales life cycle, throughout the product's life. Moreover, Srivastava identified research opportunities based on effective data-sharing through collaboration and cooperation between brokers, customers, and producers of virgin materials, as these actors are not amongst the frequently investigated actors involved in collection and reprocessing. Daugherty et al. (2005) found that resource commitment to information

[11] However these markets might be characterised and defined.

technology leads to superior performance in product recovery processes even when competitors jointly invest in information and communication systems (Asif, 2011; Toyasaki et al., 2012; Garcia-Rodriguez et al., 2013).

In addition to the frame of reference considered by Jamshidi (2011), Flapper et al. (2005) developed the most complete framework for the analysis of closed loop supply chains, while studying recovery processes at a number of large companies such as Hewlett Packard, Mercedes, Whirlpool, Heineken, and Rotterdam Port. The insight that products that can be recovered may come from, flow through and end up at the different stages of a product's life (such as fabrication, transportation, storage, reprocessing, and use) is the main strength of this framework. In addition, the framework allows researchers to explore the movement of goods and people in inter-organisational relationships that involve maintenance, repair, and operations, as well as between actors that repeatedly exchange load carriers such as trucks, containers and other types of packaging. Moreover, the framework addresses the problem of abundance and the lack of information in an effort to decrease uncertainty and create greater uniformity. This could be a difficult task because there is a greater need to obtain, gather and handle data about the conditions, places, times, reports to governmental regulators, grading rules, decision trees of different routings and recovery options, maximum stock levels and demand (ibid.).

Information and communication technologies play a key role in the organising and integration of Closed Loop Supply Chain Management activities because they allow the reduction of uncertainties, and promote cost efficient and thus environmentally friendly, routings[12] and more efficient matching of supply and demand (Dekker et al., 2004; Kokkinaki et al., 2004; Ketzenberg et al., 2006; Toyasaki et al., 2012). It is crucial to use sensors that can track increasingly complex products during their whole life, and to build a knowledge base, as well as to keep track of experience, in order to improve performance of standard routines and procedures (Flapper et al., 2005; Kumar and Rahman, 2013; Zhou and Piramuthu, 2013). Stigler (1951) recognised this issue and the need for coordination in multiple product firms undertaking a wide range of activities, which is highly relevant for firms in product recovery settings. Product proliferation in forward physical flows can increase the complexity and costs of reverse supply networks (Huang and Su, 2013).

The most important influence of the work of Jamshidi (2011), and Flapper et al. (2005) on this study comes from the fact that conventional processes in distribution, marketing and Supply Chain Management literature, such as manufacturing, storage, and transportation, are interdependent with the product recovery processes (including collection, disassembly, remanufacturing, and recycling). These interconnected activities need to be described as an

[12] Sorting and grading close to the source may reduce transportation costs and provide an early determination of the path of the item and the product recovery option (Fleischmann et al., 2001).

integrated part of the business networks, since the waste is generated throughout the production, distribution, and use stages of a product's life. Therefore, the primary end users of a final product are only one type of supplier of the products aimed for recovery.

The organising of integration and coordination of supply and demand of different inbound and outbound flows has been recognised as the key factor contributing to efficiency in product recovery (Fleischmann et al., 2000; Flapper et al., 2005; Yalabik et al., 2005; van der Wiel et al., 2012). Winkler (2011) claimed that closed loop supply chain networks can be successfully managed via the implementation of win–win relationships and cooperative technological development. Nevertheless, interaction between players with different goals and market power, and their impact on the secondary markets and network structures, has been a largely neglected research area within the product recovery field (Fleichmann et al., 2001; Toffel, 2004; Srivastava, 2007; Srivastava, 2008; Guide and van Wassenhove, 2009; van der Wiel et al., 2012; Toyasaki et al., 2012; Choi et al. 2013). An example of research with a more behavioural and governance focus on inter-organisational coordination of product recovery is that by Flygansvaer (2006), Choi et al. (2013), Krikke et al. (2013), Jena and Sarmah (2014), and Zhang et al. (2014), who demonstrated that different methods of organising affect efficiency of processes, as well as collection rates, in reverse distribution systems. Jena and Sarmah (2014) analysed competition and cooperation in a closed loop supply chain consisting of two competing remanufacturers and a retailer, without taking into consideration the wider network into which these firms are embedded. However, they argued that it is most profitable for all three firms to cooperate, as opposed to mere channel cooperation between each remanufacturer and the retailer.

Although Huge-Brodin (2002) conducted work on different types of behaviour in relationships of the logistics systems for recycling, there is a gap in the literature that can justify more theoretically based research about cooperative behaviour and coordination between organisations in business networks that deal with various product reprocessing alternatives, such as repair, recycling, and remanufacturing. Govindan et al. (2013, p. 330) concluded that most of the papers that deal with inter-organisational coordination *'within both forward and reverse supply chains focus on simple 1-1 structures with less attention paid to multi-echelon settings … the analysis of contract implementation among supply chain members is definitely worth increased attention both in theory and practice'*.

Furthermore, Håkansson and Waluszewski (2002) analysed cooperative technological development in the network of firms for recycling of paper, but did not focus on daily organising of the network for product recovery with several product recovery options. Huge-Brodin (2002), Håkansson and Waluszewski (2002), Toffel (2004), and Cheng and Lee (2010), are examples of relatively uncommon theoretically grounded essays and studies within the research area of product recovery. Rubio et al. (2008) argued that: *'The majority of articles centre on the study of tactical and operational aspects like production planning and* *inventory management, deriving from the implementation of a reverse logistics system … although we consider that more research on strategic factors (marketing, competition, technology) seems necessary in order to develop a theoretical framework for research.'* Sheriff et al. (2012, p. 186) argued in their review of strategic product recovery management that there is a lack of research on how firms cooperate, since, '*In the recent past, the increased interest of people towards reverse logistics was mainly due to various competitive forces.'*

The holistic and systemic approach undertaken by Flapper et al. (2005) and Winkler (2011) of a closed loop process that could both be under a single firm's loose or tight control and/or jointly coordinated between different organisations is adopted in this study. An element that deserves further elaboration in the framework of Flapper et al. (2005) is based on the fact that organisational issues are only seen as one metric, auxiliary to the technical, environmental and economic factors, and not as a major driver of change in the organising of business networks (ibid.). The influence of the nature of business relationships and reverse channel leadership on cost minimisation, and the overall improved efficiency regarding the organising and performance of product recovery networks was described by Östlin et al. (2008), Chan (2007), and Choi et al. (2013). Choi et al. discussed the impact of channel leadership by a number of alternative actors in a closed loop supply chain consisting of an Original Equipment Manufacturer who is simultaneously a manufacturer and a remanufacturer, a collector, and a retailer of the remanufactured products. The paper concludes that the retailer-led chain is the most optimal one, due to the retailer's proximity to the secondary end users.

In general, the integration and coordination of physical flows between a set of actors from the source to the end user enhances efficiency and effectiveness in business networks, as emphasised in the Industrial Network Approach (e.g., Gadde and Håkansson, 2001; Håkansson et al., 2009; Gadde et al., 2010) and Supply Chain Management literature (e.g., Christopher et al., 2002; Jüttner et al., 2007; Jüttner et al., 2010). Another central factor in product recovery is that a large number of companies involved in product recovery are intertwined with firms that are part of forward production-distribution networks. Indeed, Seitz and Peattie (2004) argued that product design, manufacturing, forward logistics and product recovery should be treated as integrated components of a total system. In line with this, Insanic and Gadde (2014, p. 262) argued that '*Recent research has identified various benefits associated with a holistic and integrative framing of product recovery.'*

1.3 Aim and structure of the study

There is a need for more research on the role of inter-firm organising of product recovery. Several issues that deserve a deeper understanding and more focused research attention have been identified with respect to organising product recovery. These issues include, among other things, supply uncertainty of product recovery, which, in turn, requires inter-organisational coordination. Furthermore, organising and inter-organisational structures have an impact on economic outcomes of product recovery, which is an additional reason for conducting an investigation of organisational relationships in product recovery settings. The lack of inter-organisational coordination in collection and transportation creates a large number of low-volume physical flows, which is both a costly and environmentally unsound practice.

A supplementary aspect that influences the matching of supply and demand in product recovery is the handling of the uncertainty, lack, abundance and complexity of information in demand. For that reason, it is also crucial to investigate how actors organise data exchange and classification of information regarding product recovery structures across business units, in order to enable physical flows. The study of product recovery organisation requires a holistic framework for the analysis of business relationships in which interactions and interfaces among organisations should play a central role. This implies that there is a need to study product recovery organisation from a more relational and differentiated view that involves multiple reprocessing alternatives, such as recycling and remanufacturing, and their connections to forward physical flows.

Against the background discussed in this chapter, it is now possible to state the aims of this study. The primary aim is to develop a framework for the analysis of the organising of product recovery networks and the relationships out of which these business networks are made. The secondary aim of this study is to analyse organising product recovery between firms by applying the analytical framework in an empirical study of product recovery in networks from a relational perspective.

This introductory presentation of the background and the research field of interest articulate the aim of the thesis. In Chapter 2, the analytical framework that will be used to analyse the empirical data is described. This frame of reference is based on previous research on product recovery, classification systems, and the Industrial Network Approach, with its three layers of activities, resources, and actors. The methodological considerations of this thesis are discussed in Chapter 3, including the research process, the choice of methodological approach with respect to data collection/analysis, and the quality of the study. Chapter 4 presents the empirical findings; that is, provides a case description of the PC industry from the perspective of a remanufacturer. In this empirical illustration, the focal actor is a firm that coordinates product recovery activities with regard to the different needs of disposers. These empirical findings are analysed in Chapter 5, by applying the analytical tools from the theoretical framework. The second case study, which takes the viewpoint of the disposer, is empirically described in Chapter 6, and its analysis is presented in Chapter 7. Chapter 8 includes a discussion related to organising issues in product recovery arrangements, which is based on the results of the analysis. Theoretical and practical conclusions and implications are presented in the final chapter of the thesis, Chapter 9, as well as recommendations for further research.

2 FRAME OF REFERENCE

This chapter develops the frame of reference for this thesis. The starting point and the first section of the chapter is an introduction of the context of product recovery in terms of its characteristics, activities and typical supply and demand situations. Next, a rationale for adopting the Industrial Network Approach to studying product recovery will be given. This approach contains three layers: activities, resources, and actors, which are elaborated with an emphasis on organising product recovery in detail in sections 2.3, 2.4, and 2.5. After each section associated with a layer of the Industrial Network Approach, research issues are formulated. Section 2.6 outlines the analytical tools used for the study of the role of the classification systems in organising product recovery. The research issues and the frame of reference are summarised in section 2.7.

2.1 Essentials of product recovery

A large number of organisations are involved in the physical flows of goods, materials, components, parts and products that might need to be recovered or disposed at waste sites. These items may appear at different locations or points in time, during or after use, or at another stage of life of a product, such as testing of a faulty component before the assembly or quality control of production defectives in a factory before shipping. For example, during and after use a customer can have her or his car repaired or sold to a car dealer, who may then repair the car so that it can be sold or distributed to another customer. Other examples could be items damaged during materials handling or transportation, unsold/obsolete components, or end-products in warehouses located at different geographical sites, owned by logistics service providers, distributors, or retailers.

Organisations are involved in complex production, distribution, and utilisation arrangements in business networks. Proliferation and uncertainty about the timing, quality of materials, and sources or supply of products that could be recovered depend on the quantity and variety of actors involved in production, distribution, and use. This is one of the causes of the various challenges related to uncertainty that firms involved in product recovery attempt to manage. Various aspects of uncertainty are often important for these firms to consider. Fleischmann et al. (2000, p. 664) argued that *'Supply uncertainty both in quantity and quality appears to be a major distinction between product recovery networks and traditional production-distribution networks.'* These uncertainties take the form of variability in volume or low degrees of economies of scale, variability in quality and the state of product, or labour-intensive selection/disassembly of products, parts and materials and variability in the type of returned products or the allocation of products to different purposeful reprocessing facilities (Pohlen and Farris, 1992; Flygansvaer, 2006; Tuzkaya et al., 2011).

Guide et al. (2000), Ketzenberg et al. (2006), Tuzkaya et al. (2011), Asif (2011), Toyasaki et al. (2012), and Garcia-Rodriguez et al. (2013) elaborated further about the nature of uncertainties. First, uncertainty concerning the timing and quantity of products available for acquisition is important. This reflects the nature of a product's life. Hence, depending on the nature of the product, it can be more or less possible to know when it will be 'ready' for product recovery. This, in turn, is associated with the sales life cycle of products and the rate of technological change. Another uncertainty is the quality of the product. Two seemingly identical products delivered to the primary end users and that eventually enter the recovery system can turn up in different shapes due to the variety between the usage patterns, and may need alternative recovery options. The condition of the product is also a decisive factor in choosing the recovery option, and often this decision cannot be made until the product has been more or less disassembled. The state of the product is age-, environment-, and usage-specific (Guide et al., 2000). Linked to this is the fact that products can be more or less difficult to disassemble, depending on their design (Bostel et al., 2005; Mathieux et al., 2008; Mutha and Pokharel, 2009; Winkler, 2011). The modular design increases the profits of both forward and reverse supply chains (Kristianto and Helo, 2014). Thus, the degree to which the product is designed for recycling or remanufacturing has a great impact on how product recovery can be accomplished (ibid.). How the products are collected and brought to the recovery centre is another uncertainty that needs to be considered. This can involve decisions regarding transportation modes and facilities, as well as the involvement of third party logistics providers (Guide et al., 2000; Ko and Evans, 2007; Cheng and Lee, 2010; Guarnieri et al., 2014). Furthermore, handling of packaging material and shipping material can be considered in this context. In order to handle these challenges, firms try to organise product recovery activities in a way that reduces these uncertainties (Krikke et al., 2013).

An additional uncertainty is the place or source at which the product to be recovered will be located, and how the recovery firm can connect to the source in question. The sources can also be described in terms of customers, suppliers, brokers, and manufacturers, as well as other third-party vendors, which are all parts of forward physical flows. These forward physical flows of materials, parts, and products consist of the stages in the production, distribution, and use processes. The life of a product is usually described as sequential phases through which raw materials are formed into new offerings. Boundaries between these three stages are blurred, and not as clear as they are portrayed in the oversimplified and primarily schematic Figure 2.1.

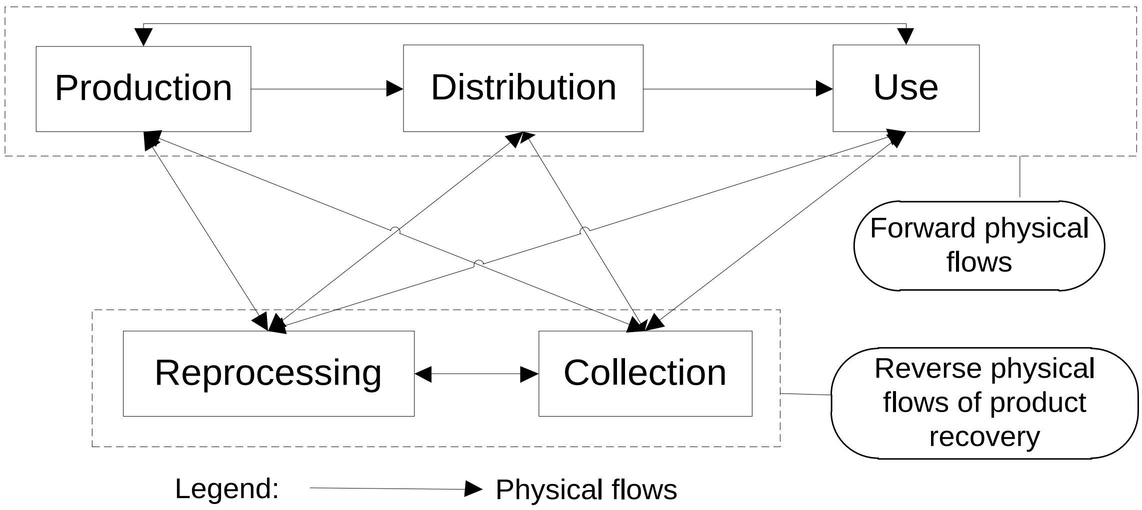


Figure 2.1 Closed loops related to different phases in the life of a product (adapted from Flapper et al., 2005, p. 5).

Figure 2.1 illustrates that forward and reverse stages of physical flows can be combined in numerous ways at different points in time (Fleischmann et al., 2005). *Collection* and *reprocessing* are two stages that represent reverse physical flows. Prior to describing collection and reprocessing activities (such as recycling) of product recovery milieus, there is a need to explain what triggers reverse physical flows in space and time during production, distribution and use. Product recovery might take place for a variety of reasons during a product's life (Flapper et al., 2005; Jamshidi, 2011), such as:

- *Production related (for example, from manufacturing facilities).* Obsolete materials (surplus production, components or semi-finished products, production scrap) and production defectives (products not conforming to some pre-set quality levels, which are scrapped or reprocessed to a level where they can be sold as initially intended, or as a lower-quality product).
- *Distribution related (for example, from distributors, retailers, third party logistics providers and users).* Commercial returns, order cancellations while the product is on the way to a certain customer, surplus stock, unsold stock returns, damaged goods/packaging, defective deliveries that do not conform to specifications, and recalls (returns in the context of actual or expected problems with products).
- *Use related (from end users).* The same or replacement products that should eventually be returned to the current users (repairs, warranties and recalls), or, in cases where companies are offering repair, refurbishment or remanufacturing of the products, products returned to the supplier (end-of-lease products), and products returned at the end of their technical or useful life from the point of view of their current user or their original manufacturer, which may still start a new useful life in a different market.

- *End-of-life (from end users).* Products returned to the distributor or producer because they reached the end of their useful life. Their components and materials may be reused in other products.

To exemplify this variety, Håkansson and Waluszewski (2002) noted that waste paper may be collected from publishers, industrial converters, retailers and households. Consequently, there is a variety of sources of recoverable products. In the present study, the primary focus will be on the users in their role as a source for product recovery.

Having discussed the sources of supply of materials that can be recovered, the next step is to consider different options for how this recovery can be accomplished. Fleischmann et al. (2005) noted that some materials may flow through the supply–production–distribution–use–recovery network in several cycles. Figure 2.2 illustrates one such alternative path through several cycles, where returns from production and distribution stages are not considered.

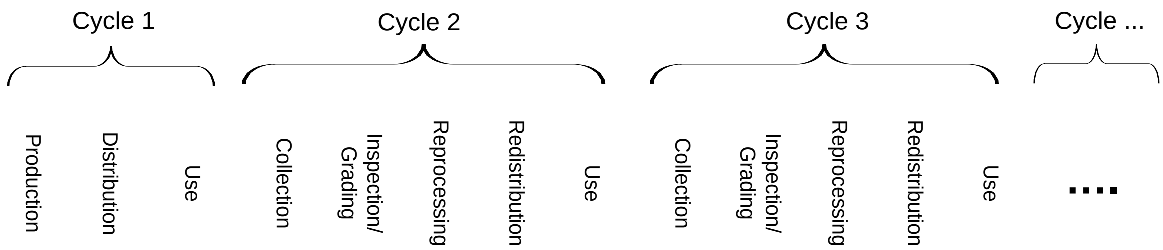


Figure 2.2 Supply–production–distribution–use-recovery cycles (adapted from Fleischmann et al., 2005, p. 176).

Whenever an object (product, material or component) in the production, distribution or use phase is disposed of, the recovery phase of *collection* is crucial as it enables the other stages to continue. Products that are collected from the disposal sites are transferred to facilities where they can be *inspected* and *reprocessed*. The recovery phase of reprocessing into material fractions or component parts is not always necessary, for instance if the surplus stock of unsold items from a production facility is passed on to an actor that specialises in the distribution of models the manufacturer regards as outdated. *Inspection* and classifications occur when there are uncertainties about the state of products, such as when deciding which reprocessing option is most appropriate for the context in question. *Reprocessing* is a part of the extended supply chain in Figure 2.2 that can be divided into several activities or sub-processes depending on whether products, components or materials are decomposed or disassembled into materials or parts (Thierry et al., 1995). A more elaborate description of these activities is presented in section 2.3.1.

A variety of companies and organisations perform different steps of collection, inspection, reprocessing and distribution to new users under these arrangements. Therefore, the next section provides an argument for applying a network perspective to how product recovery is organised.

2.2 A network approach to organising product recovery

There are many sources of products that can be recovered, in addition to many users and potential uses of recovered products. These sources and users can be connected in a great number of ways. This requires organising efforts between specialised business units that are responsible for their resources and activities. Consequently, products, parts, components and materials that may be recovered can be collected from different sources at different times and delivered to various actors. As previously mentioned, it is not obvious where a certain recoverable product will flow through, either with regard to how it is classified in the process from ‘source to use’ or where it will end up. Furthermore, this reverse flow can be more or less integrated with the forward physical flow (e.g., Fleischmann et al., 2001; White et al., 2003; Flapper et al., 2005; Garcia-Rodriguez et al., 2013).

All in all, the multitude of options available for product recovery, and the complex inter-organisational context in which it is performed, calls for an integrated and holistic network approach for its analysis. Several authors who have performed literature reviews of Closed Loop Supply Chain Management and product recovery (Srivastava, 2007; Guide and van Wassenhove, 2009; Sharma et al., 2010; Govindan et al., 2013), have noted that there is a need for further research on business relationships, in order to gain an understanding about how the nature of relationships affects the performance and operational design of product recovery in business networks. Winter and Knemeyer (2013) claim that several researchers have highlighted the need for a transfer of existing theoretical approaches to analyse product recovery configurations.

Toffel (2004) and Cheng and Lee (2010) analysed dyadic aspects of product recovery using the Resource Based View (e.g. Penrose, 1959; Grant, 1991, 1996), which mainly concentrates on the resources utilised by single firms, and Transaction Cost Economics (e.g. Williamson, 1975, 1985), which primarily focuses on transaction costs or transaction activities in dyadic business relationships. A more inclusive framework is needed in order to conduct research on relationships between interconnected actors that are involved in product recovery, and the type of resources that are combined in order to perform activities related to that recovery. Researchers and academics have already conducted successful studies on business environments of complex network structures in forward physical flows (e.g., Anderson et al., 1997; Silveira et al., 2001; Gunasekaran and Ngai, 2005; Hertz and Alfredsson, 2005).

This study is therefore influenced by a network perspective on product recovery, with its point of departure rooted in the Industrial Network Approach (Håkansson, 1987; Håkansson and Snehota, 1995; Håkansson et al., 2009). The holistic nature of the research project – that is, sustainable development of logistics structures – and the long-term perspective of sustainability issues have made dyadic and focal-firm-centric theoretical approaches insufficient as analytical tools. A network view of product recovery makes it possible to analyse interaction and collaboration among several parties, as requested by Fleischmann et al. (2000), Choi et al. (2013), Govindan et al. (2013), and Winter and Knemeyer (2013). With this in mind, inter-organisational issues become crucial, since product recovery is performed by a number of independent firms that specialise in various parts of the system (Knemeyer et al., 2002). In addition, the rationale for utilising the Industrial Network Approach as a starting point in this study rests on the recognition that this approach offers a rich set of concepts reflected in three network dimensions of activities, actors and resources. Each dimension of the Industrial Network Approach will be more closely elaborated in separate sections, in order to illustrate the interrelatedness between the layers within the context of product recovery.

The idea of network takes into account the dynamics of relationships in the wider business landscape (that is, beyond single transactions or relationships). As the Industrial Network Approach was developed for the study of existing exchange relationships in several directions (Gadde and Ford, 2008), it is very well suited as the basis of a holistic framework for the analysis of relationships between firms that are involved in product recovery contexts. By conceptualising the process and outcomes of interactions, the Industrial Network Approach makes it possible to analyse business relationships in networks. In this way, the Industrial Network Approach enables an analysis of the current state and development of inter-organisational relationships in business networks across company boundaries through three complementary layers: activity patterns, resource constellations and webs of actors (ActivityResourceActor model), as portrayed in Figure 2.3.

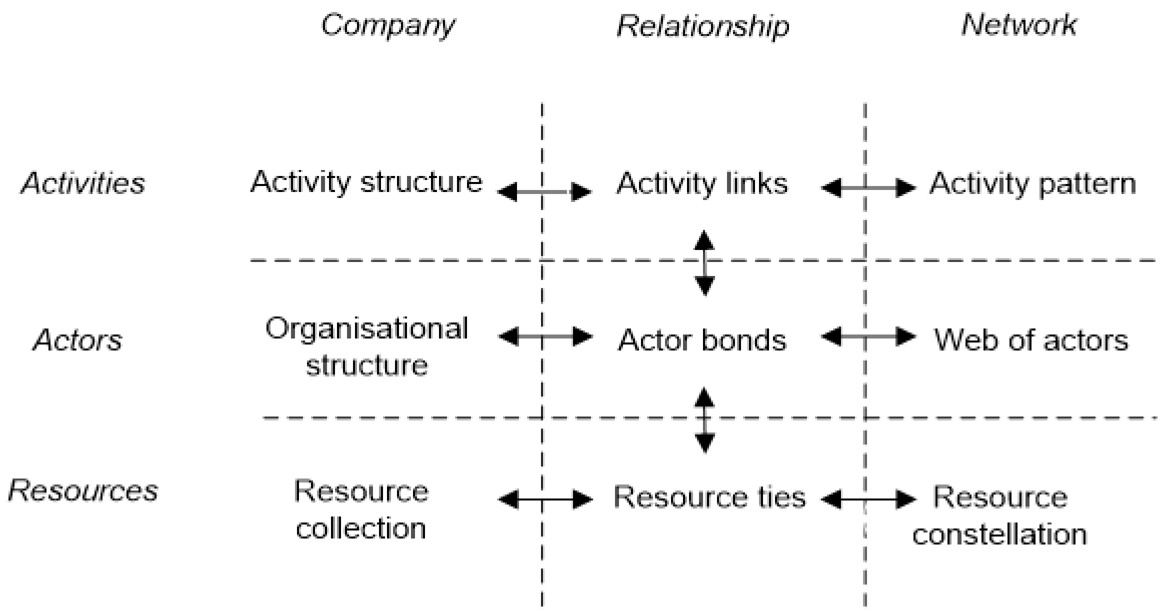


Figure 2.3 Scheme for the analysis of business relationships, the Activity-Resource-Actor (ARA) model (Håkansson and Snehota, 1995, p.45).

The constellation of resources, pattern of activities and web of actors in a business network influence each other. As a matter of fact, all of these layers are interdependent; however, separate analyses make it possible to get a grip on the complexities of the reality (Gadde et al., 2010).

The activity layer is used in the analysis of integration and linking of activities. It has been shown that a lack of integration and insufficient activity linking can have a substantial economic effect on interacting parties (Richardson, 1972; Dubois, 1994). Adjustments between activities may function as synchronisation mechanisms in the organising of physical flows, as in the case of 'just in time' production (Gadde et al., 2010).

The resource layer is related to adaptations that create resource ties between actors that are interacting in a network. These ties are intended to make resource utilisation more efficient (Håkansson et al., 2009). In addition, systematic combinations of tangible resources, such as physical items, and intangible resources, such as knowledge, are significant for the utilisation, efficiency and innovative combining of resources. Jahre et al. (2006) argued that adaptations in the resource layers between organisational units in reverse logistics networks have not been developed to the same extent as in other established logistics networks. This is due to the fact that recycling for many products, such as electronics, was not legally enforced until the last decade of the twentieth century (ibid.). At that time, actors involved in the production of these kinds of products were made responsible for taking care of them at the end of their useful life.

Activity adjustments and resource adaptations are generated in the *actor layer* by interaction between organisations. Interaction between companies creates a great deal of diversity among actors who perform differentiated activities using resources in larger groupings of networks, identified as actor webs (Gadde et al., 2010). Furthermore, actors also develop bonds, which consist of mutual orientations, obligations, commitments and selective preferences (Håkansson et al., 2009). It is actors, such as business units, cross-functional teams, governments and corporations, which need to link activities and tie resources. Activity coordination and resource combining do not proceed in a vacuum (Gadde et al., 2010).

Business relationships are important in this respect because they provide actors with access to other organisations' resources and activities, thereby creating mutual interdependencies (ibid.). By interacting in business relationships, firms can identify opportunities for the combining of resources and the coordination of activities, which may increase the economic value of a particular resource constellation and activity pattern. In addition, different resource constellations expose a resource to tensions that can create problems in the use of other resources (Håkansson et al., 2009). On the other hand, these tensions may provide opportunities for resource development, as demonstrated by Håkansson and Waluszewski (2002) in their study of a product recovery arrangement for the handling of disposed-of paper. Prior to the 1990s, collectors of waste paper charged disposers for paper collection. When disposal and reprocessing were reorganised so that waste paper became an input product in paper production, the paper was collected for free or could even be sold to the collectors. Yang et al. (2013) claimed that coordination and collaboration are crucial when it comes to products with high deterioration rates, inventory holding costs, and price sensitivity. Furthermore, the organising efforts were proven by Huge-Brodin (2002), Flygansvaer (2006), Galbreth and Blackburn (2006), Choi et al. (2013), Krikke et al. (2013), and Zhang et al. (2014) to be central for the performance of the product recovery networks. This means that organising has a significant impact on the actor, resource, and activity layers of business networks.

Therefore, this thesis regards organising by actors as activity coordination and resource combining in product recovery arrangements. These three layers of activities, resources and actors interact in such a way that actors control and make use of resource combining and recombining when they perform and coordinate activities.

As mentioned above, research on product recovery has seldom been conducted from a network perspective of inter-organisational relationships. Thus, the following sections relate the Industrial Network Approach to product recovery. In the next section, the activity layer of the Activity-Resource-Actor (ARA) scheme for the analysis of business relationships in networks will be discussed in relation to product recovery.

2.3 Organising product recovery in activity patterns

This section outlines the theoretical frame of reference related to activities in product recovery arrangements. First of all, the section will introduce processes of product recovery settings. Then, central features associated with activities, such as *interdependencies* and *adjustments*, will be described. After that, analytical tools for the study of activities will be elaborated upon. Finally, research issues associated with organising product recovery in the activity pattern will be presented.

2.3.1 Activities in product recovery

In this section, a set of activities within product recovery and reverse logistics structures is discussed. Flygansvaer (2006) divided overall reverse distribution activity structures into five levels: primary consumption, collection, transfer, reprocessing and secondary markets. Håkansson and Waluszewski (2002) exemplified the sequence of activities of collecting waste paper from businesses and households, in terms of classification, reprocessing, and distributing the product in the form of newspapers. Thus, primary and secondary users are linked by organising physical flows in collection, transfer or logistics, reprocessing and distribution activities (Fleischmann et al., 2005). That is to say that '*The heterogeneous and uncertain nature of returns requires a set of collection, reverse logistics, and recovery systems that can be used flexibly—sometimes combined with the forward supply chain, sometimes not*' (Krikke et al., 2013, p. 249).

The product recovery processes detailed in Figure 2.4 involve some general activities that need to be undertaken between the sources of recoverable products and their use (Krikke et al., 2004). However, the order and importance of these may vary from situation to situation because they are highly intertwined. Krikke et al. (2004) and Thierry et al. (1995) defined five such basic activities. First, product *acquisition* concerns how the acquiring firm obtains the products to be recovered. Second, product *collection* concerns how the product to be recovered is collected from the source. Third, product *recovery logistics* relates to transportation from the source to the recovery facility. Fourth, *classification* is closely connected to, and a result of, testing and inspection. Classification means deciding on how to handle different products and components with regard to the recovery options discussed below. Fifth, the chosen *recovery option* (reuse, repair, refurbishing, remanufacturing, component retrieval, recycling, incineration, or disposal at landfill) is undertaken. Sixth, the products are *distributed*, either to new buyers, or for the production of new raw materials.

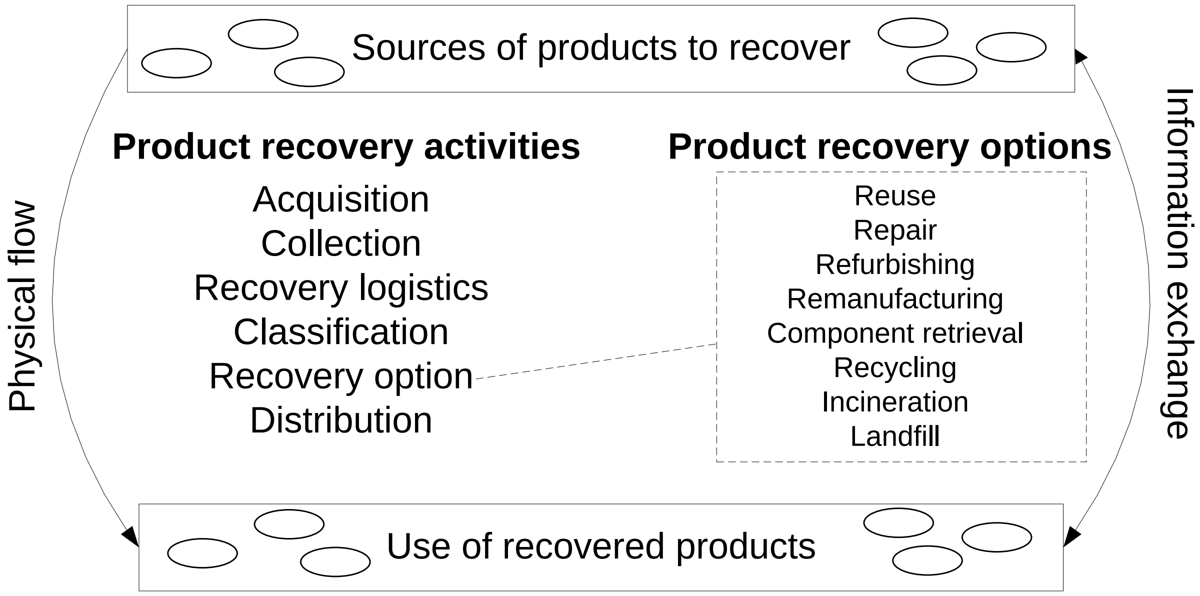


Figure 2.4 A framework of product recovery activities (adapted from Krikke et al., 2004).

Information exchange between firms is essential as a precondition for efficient coordination of product recovery processes in physical flows, as represented in Figure 2.4. Accurate information about the state of the product assists in the decision as to how to direct the products to appropriate facilities (Blackburn et al., 2004). In order for the acquired and collected product to be delivered to an adequate facility or a new buyer, it must go through the stage of reprocessing, on a product, component or material level. The aim of these reprocessing activities is to recapture value from returned products and components, with the most environmentally friendly alternatives topping the list in Figure 2.4.

Based on the models posited by Thierry et al. (1995), Krikke et al. (2004), and Garcia-Rodriguez et al. (2013) it is possible to distinguish between eight such product recovery and disposal options. First, *reuse* means checking on damage and cleaning the product. Second, *repair* aims to restore used products to working order via the repair and/or replacement of components. Third, *refurbishing* is related to bringing the quality of used products up to a specified level via disassembly, inspection and replacement of broken modules. Refurbishing could also involve technology upgrading in terms of replacing outdated modules or components with technologically superior ones. Fourth, *remanufacturing* aims to bring the used products up to quality standards that are as rigorous as those used for new products. This is done via extensive inspection and replacement of broken/outdated parts. This option can also involve manufacturing new products from old parts. Fifth, *component retrieval* aims to recover a relatively small number of reusable parts and modules from the used products, to be used in any of the four operations mentioned above. Sixth, *recycling* aims to take materials from used products and parts via various separation processes and reuse them in the production of the original or other products. The seventh and eight options are *incineration*, or energy recovery, and *landfill*.

Following this discussion of activities within product recovery, we will now address certain general features of activities portrayed in the Industrial Network Approach and the ARA model. This model makes certain assumptions with regard to central features of activities, as presented below.

2.3.2 Central features of activities

The activity layer of the ARA model enables a focus on a separate aspect of this complex reality. Business networks can be described in terms of patterns of interlinked and interdependent activities by focusing attention on the activity layer (Håkansson and Snehota, 1995). Here, activity interdependencies and activity adjustments will be illustrated together with the principles of postponement and speculation, with the intention of connecting these concepts to product recovery arrangements.

Activity adjustments

Adjustments to activities are developed to handle interdependencies; in turn, these adjustments create incentives for increased integration between activities (Håkansson et al., 2009). An example of an adjustment is the synchronisation of transportation and product recovery options. Hence, a truck may wait for a refurbishing operation to be finished in order to transport the product in question to an intermediary or an end user. Another type of adjustment may involve the modification of administrative routines for offering, ordering, confirming, and providing delivery notification, which is frequently the case when a business relationship is characterised by the exchange of a large number of documents (ibid.).

Activity adjustments serve as a method by which to increase activity integration, as well as a means of handling interdependencies (Håkansson et al., 2009). An example of activity adjustment is a ‘just in time’ solution. These solutions improve joint performance between companies, while at the same time requiring substantial investments that might constrain adjustments between other activities (Bankvall, 2011). Increased interdependence in ‘just in time’ solutions also implies that a customer company is dependent on the delivery reliability and continuous flow of inputs from a specific counterpart. Another constraint that is inherent in activity adjustments is the fact that a huge variety of requests from different customers leads to difficulties in reaping economies of scale (Håkansson et al., 2009). If all buyers decide separately what to order, without any extensive interaction with the seller/supplier, their orders can lead to considerable diversity in the supplier’s activity structure. On the other hand, a group of buyers may jointly plan for the increased exploitation of a seller’s economies of scale. Fundamentally, this is the problem of handling the combined requests for variety in particular purchasers’ requirements of products and services, and cost efficiency related to economies of scale. These aspects are presented below.

Activity interdependencies

A framework, inspired by Richardson (1972), for analysing interdependencies between activities that extend over a network of actors in business arrangements has been developed by Dubois (1998) and Dubois et al. (1999). The starting point of these authors' analytical framework is the dependence among the activities across and within firm boundaries. Therefore, single activities should not be studied in isolation. Accordingly, Gadde and Håkansson (2001, p. 59) stated that: *'At a specific point in time the activities in the network are characterized by a certain division of labour among the firms involved.'* Krikke et al. (2013) acknowledged that product recovery activities are also outsourced in several layers, with each firm specialising in a number of functions. Thereby, since activities are related to each other and performed by different actors, there will be certain prerequisites for efficiency within activity structures (Dubois, 1994). Dubois et al. (1999) argued that there are two types of dependencies that coexist at the same time, *sequential* and *parallel,* as elucidated in Figure 2.5.

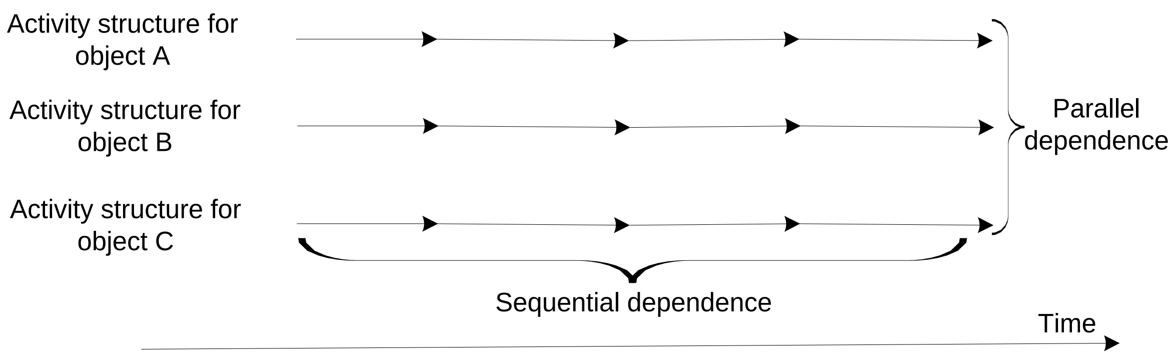


Figure 2.5 Parallel and sequential dependence of activities (Dubois et al., 1999, p. 14).

One kind of activity dependency is the existence of *sequential dependence* (ibid.) or the fact that activities are *complementary* (Richardson, 1972), which stresses the fact that one activity is related to activities performed prior to, as well as after, it. Complementary activities need to be coordinated because such operations must be undertaken in a specific predetermined order (Gadde et al., 2010). In addition, *closely complementary* activities need to be coordinated to a larger extent, since they are directed towards a specific end user. Such activities may exist partially or completely in an activity pattern, and need to be planned through exchanges of information, such as orders, confirmations and delivery plans (Dubois et al., 1999). When closely complementary activities are undertaken by several firms, it is necessary that '*organisations agree to match their related plans in advance*' (Richardson, 1972, p. 890). However, close complementarity, combined with an increased level of *diversity* due to counterpart specific adaptations, reduces opportunities for scale-efficient operations, as many activities become highly customised and dissimilar. Moreover, proliferation of products in forward supply networks increases even the overall expenses of reverse physical flows due to changeover delays in reprocessing, and decreased batch sizes, which in turn affects shipping costs to a large number of actors (Huang and Su, 2013).

Parallel dependence, another type of dependency in the activity pattern, is related to common use of resources (Dubois et al., 1999). This involves *similarity* among activities. Similarities provide cost advantages due to routine reuse of knowledge. Routines are central to all activity patterns, whether in manufacturing, banking, logistics or consultancy services (Håkansson et al., 2009). Similar activities are those that *'require the same capability for their undertaking'* (Richardson, 1972, p. 888). This means that these activities performed on objects make use of the same resources. Similarity may involve activities that use the same machinery and equipment, the same workforce capabilities, the same transportation facilities, and so on. Similarity is related to standardisation and economies of scale, which promotes specialisation (Gadde et al., 2010). For example, standardisations of load carriers or object classes create similarity in the activity pattern, since they enable parties to economise on their scale of operations (Håkansson et al., 2009). In this manner, a pallet, trailer, container or business unit may be designed to facilitate parallel dependencies. This can be the case when an organisation orders products from a supplier firm, which are currently in possession of a third organisation. All in all, firms try to manage economies of scale and sequential coordination of activities in order to keep inventory costs at as low a level as possible.

Nevertheless, the discrepancies between the operating ratios of the different activities that connect different steps in a network involving product recovery may create time discrepancies, which requires increased inventory. An example of interaction between these factors is portrayed by Bucklin (1965, p. 28): *'As the delivery time to be allowed increases, it becomes possible to reduce the safety stocks, increase the turnover and reduce the size of the facilities and interest cost.'* The same effect for the receiver of the goods is available when frequent, rapid deliveries are introduced into logistics structures. Such factors have been studied using principles such as *postponement* and *speculation* in forward distribution (Abrahamsson et al., 1998; Pagh and Cooper, 1998; Waller et al., 2000; Hulthén, 2002; Jensen, 2009), in reverse logistics systems for recycling (Jahre, 1995; Huge-Brodin, 2002), and, more generally, for commercial returns with several reprocessing options (Blackburn et al., 2004). These principles for analysing structures and efficiency of physical flows in business networks are portrayed in the following section.

Principles of postponement and speculation

The principles of *speculation* (Bucklin, 1965), *postponement-speculation* (ibid.) and the *principle of postponement* (Alderson, 1950) are descriptive of the archetypes of logistics structures. They provide rules for organising activities in time and the impact of distance and economies of scale on temporal structuring of physical flows of articles that are classified and transported by freight forwarders through many inventories (Bucklin, 1965). More importantly, the principles of postponement and speculation relate to the role of speculative inventories connected to the risks of ownership, because such inventories need to hold uncommitted stocks at the risk of their remaining unsold (ibid.). The study of uncertainty and differentiation of products in, for example, refurbishing or recycling should make these principles a suitable starting point for a detailed theoretical description of distribution activities within product recovery contexts.

Product differentiation can occur in various guises, as Chamberlin (1946, p. 36) noted: *'By variation (of the product) we may be referring to a modification of the quality of the product itself – technological changes, new model, better raw materials; we may mean the packaging or a new recipient; or, finally, we may mean better and more friendly service, a different way of doing business.'* Alderson (1950, p. 1) regarded the principle of postponement of differentiation as one of the most general methods that *'can be applied in promoting efficiency'* of a business network by postponing *'the changes in form, identity and location to the latest possible point in the marketing flow.'* This means that the point in time at which activities become closely complementary is delayed. However, activity similarities and parallel interdependence among activities also need to be considered. Therefore, savings in the physical movement of goods through time can be achieved by sorting[13] products into large lots and relatively undifferentiated states. Risk and uncertainty costs are tied to the differentiation of goods through the principle of postponement because *'every differentiation which makes a product more suitable for a specified segment of the market makes it less suitable for other segments'* (Alderson, 1957, p. 424). That is to say, the properties of objects in time (such as delivery date), form (including technical specifications), place (such as shelf space) and identity (end user characteristics), are unchanged until an order is received. The *identity* dimension of a product is related to a specific actor, implying that the object is assigned to that actor (Hulthén, 2002). Hence, products are customised in order to be assigned the identity of an end user or a specific counterpart (ibid.).

For example, in the PC industry, if computers and monitors are remanufactured speculatively to certain specifications in size, processor speed, memory and other form features, and are sent to a specific store in a particular country and city, this increases the risks of them not being sold, as it narrows down the number of potential secondary users. Thus, a more or less generic product-service offering is stocked and additional features and options are added when an order is received. Delayed differentiation is introduced into the logistics network to avoid the costs of carrying separate inventories of all varieties of the final product.

As Alderson (1950) noted, the principle of postponement can be carried to absurdity if every activity is postponed until the latest point in time, as the user would then be handed raw materials[14] and asked to make the best use of them. Therefore, postponement must be

[13] This term will be elaborated thoroughly in section 2.3.3.

[14] This could also apply to recycled raw materials.

balanced with the principle of speculation. This principle is based on expectations of demand, and states that *'changes in form, and the movement of goods to forward inventories, should be made at the earliest possible time in the marketing flow'* (Bucklin, 1965, p. 68). This temporal rule for organising activities leads to enhanced similarity of activities in order to reduce the costs of production, distribution, and stock-outs. With regard to the buyer (whether industrial or private), activities resulting from speculation are *complementary* but not *closely complementary*, since speculative inventories are not assigned to any specific end user.

Bucklin (1965) argued that channels in their totality cannot avoid speculative inventories because some organisation, or group of organisations, must continually bear this uncertainty. Such inventories move risk away from those organisations that supply, or are supplied by, the inventory (ibid.). Jahre (1995) and Blackburn et al. (2004) focused on operational issues in terms of using delayed or early differentiation of returns with respect to trade-offs between efficiency of fill rates in collection and efficiency in sorting. For example, separation or differentiation of returns can be done early in a *decentralised manner* at disposers' premises. Differentiation of returns can also be delayed until goods arrive at a *centralised* inspection facility, as various types of goods can be co-collected for efficiency in transportation and storage in order to be directed towards dedicated reprocessing or distribution facilities (Blackburn et al., 2004). Figure 2.6 provides an illustration of principles of postponement and speculation within product recovery settings.

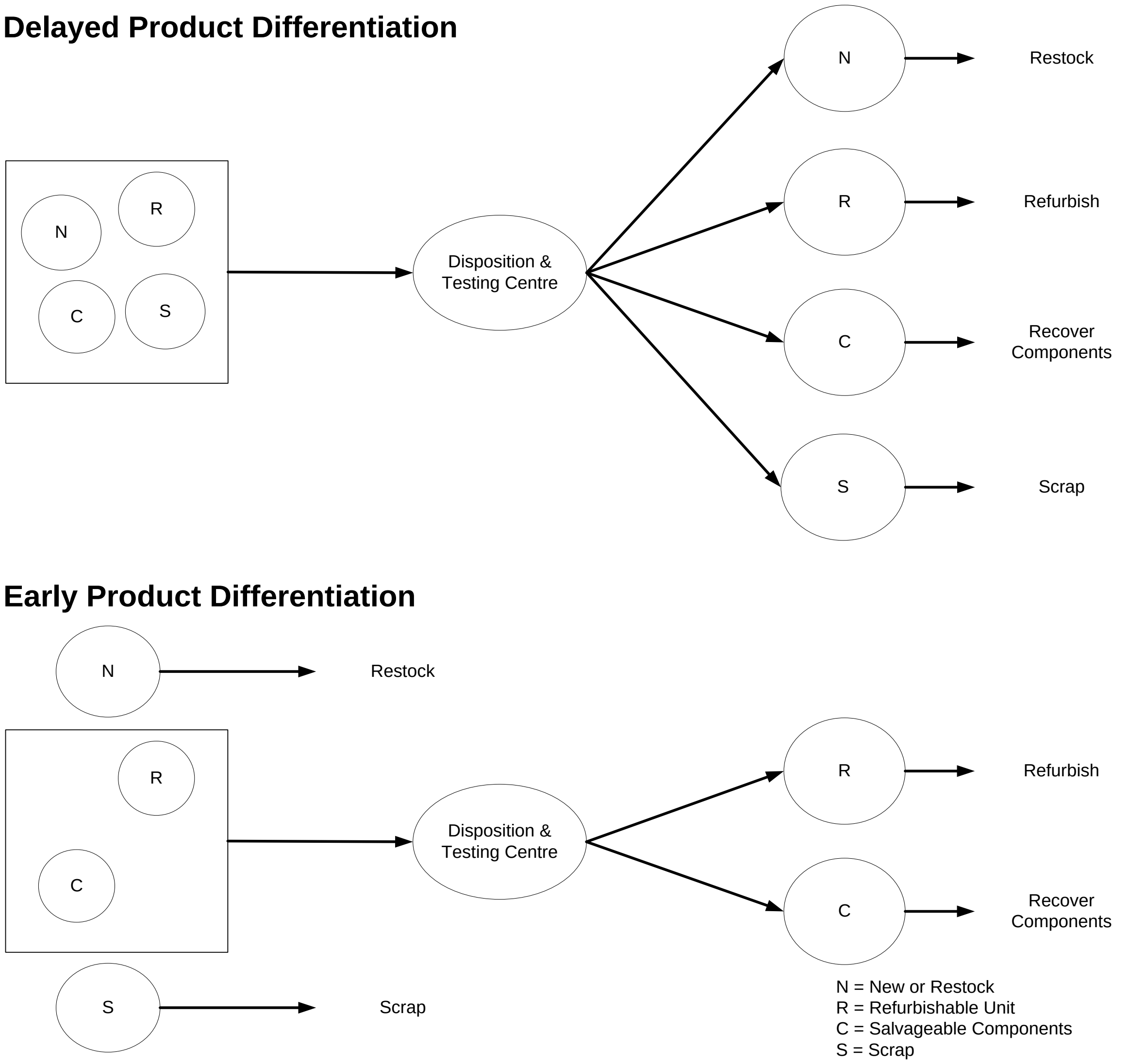


Figure 2.6 Principal distinctions between delayed product differentiation (postponement) and early product differentiation (speculation) (Blackburn et al., 2004, p. 15).

All in all, postponement is important in the customisation and minimisation of unnecessary carrying time, while speculation is crucial in capturing similarities. These two principles, combined, serve to progressively reduce the cost of labour and investment per unit of product. The development of information technology has created the possibility of speculating information about supply and demand in a ‘stock’ that is accessible to all parties involved in the business network, which, in turn, enables increased application of the principle of postponement. Wu and Dunn (1995), as well as LaLonde and Mason (1988), explained that leading firms have replaced speculative inventories in several stages of business networks by means of adequate information sharing in collaboration with their partners. Similar findings in reverse distribution and product recovery arrangements have been demonstrated by Festus and Li (2010). Håkansson et al. (2009) arrived at the same conclusions, stating that efficiency in information exchange activities and activity patterns in logistics could serve as substitutes for storing and warehousing. This facilitates 'build to order' production, in accordance with individual customer requirements.

Investments in collaboration-based technologies for information sharing have also been pointed out as an important factor for increased efficiency in reverse logistics (Srivastava, 2007; Zhou and Piramuthu, 2013). RFID[15]-embedded component tags generate refined information sharing and improved economic and environmental performance of reverse supply chains (ibid.). For instance, Bosch uses an inexpensive chip to record the time and speed at which its tools have been operating (Blackburn et al., 2004). Test machines at retailers employ the chip to determine whether the tools that have been run under extreme conditions (operated above a certain number of hours) can be sent speculatively and directly to a recycling centre (ibid.). The remainder that do not meet the requirements for recycling can be returned immediately to suitable remanufacturing plants.

Developments in technologies of transportation, materials and information handling, and efficient assembly thanks to modules that are used in one or several product groups, reduce risk and uncertainty. As a consequence of these technological and managerial advances, the relative advantage of speculation over postponement has been decreasing. In a product recovery environment, postponement reduces the risk of obsolescence of used products by moving the differentiation nearer to the time of purchase. In addition, modular design increases possibilities for mass customisation in both forward and reverse physical flows, as new modules and software can easily be installed to upgrade used or remanufactured items (White et al., 2003; Bostel et al., 2005; Kristianto and Helo, 2014). Shortening sales life cycles, and rapid price reductions (or faster innovation cycles), increase the risks of obsolescence of new, as well as used, products and modules. Blackburn et al. (2004) and Krikke et al. (2013) argued that product model returns for which price reduction rates are high and increasing towards the end of their sales life cycle should be managed in a quick and responsive reverse supply chain. The path of these products to suitable facilities should be determined as early as possible, as extra delays during queuing, storing, separation, and inspection are connected with a decrease in price (ibid.).

In contrast, heavy, bulky and inexpensive raw materials, such as recycled paper, are likely to flow slowly through networks using scale-efficient transport modes, such as ships, rather than air transport. In the current state of affairs there is always a demand for raw materials, which are used in an increasing diversity of products, derived through requirements for differentiation coming from the demand side of the company (Håkansson et al., 2009). The successive differentiation of the raw material as it moves through time in the business network indicates that the heterogeneity of a resource, such as recycled steel, is progressively declining while the carrying costs and risks are increasing, since this raw material can be used

[15] Radio Frequency Identification.

as an input for manufacturing specific products such as cars, bicycles, refrigerators, ovens, and construction materials. In this manner, recycled steel becomes more and more involved in the progressive establishment of actor specific complementarities, while *diversity* is gradually lost, owing to the fact that this steel can be used for a decreasing range of products.

Activity features, such as interdependencies, principles of postponement and speculation, need to be connected to analytical concepts for the investigation of activity patterns. Therefore, the next part of the chapter will describe a set of analytical tools such as the transvection and crossing and differentiation points that are used to scrutinise principles of postponement and speculation in combination with activity interdependencies.

2.3.3 Analytical tools for activities

In this section, several analytical tools are discussed. These tools will be used to analyse empirical data with a focus on activity patterns of product recovery arrangements. The starting point for the analysis of activity patterns in this study is the concept of transvection (Alderson, 1965). This concept regards all activities as either sorts or transformations (ibid.). Hulthén (2002) implemented and developed the concept of transvection by combining it with the Industrial Network Approach, in order to analyse variety in distribution networks. The following sections will describe some extensions of the framework developed by Hulthén, in order to make a connection between the concept of transvection and the product recovery context (ibid.). Furthermore, since transvections can be used to analyse the processes, they should also be well adapted to the study of collecting, remanufacturing or recycling, distribution, and other activities associated with product recovery contexts.

Transvection

Alderson (1965, p. 92) defined transvection[16] as *'a single unit of action of the marketing system. This unit of action is consummated when an end-product is placed in the hands of the ultimate consumer, but the transvection comprises all prior action necessary to produce this final result, going all the way back to conglomerate resources as they appear in the state of nature.'* Furthermore, the whole business process, consisting of numerous transvections, was described by Alderson as *'the continuous operation of transforming conglomerates as they occur in the state of nature into meaningful assortments in the hands of consumers'* (ibid., p. 122).

As illustrated in Figure 2.7, each transvection consists of a series of sorts (item classifications), interspersed with a series of transformations affecting the conditions of products in time (such as storage), place (transport), and form (manufacture) dimensions

[16] The word stems from the Latin *trans* and *vehere*, and is meant to express the meaning of 'flowing through', related to the movement of goods, people and information (Alderson and Martin, 1965).

under which the goods will eventually be brought to end users. Both sorts and transformations can be arranged in different ways, added onto a current set-up, or removed from it. In addition, at each step of the transvection, the costs of sorting and transformation are incurred (Alderson and Martin, 1965).

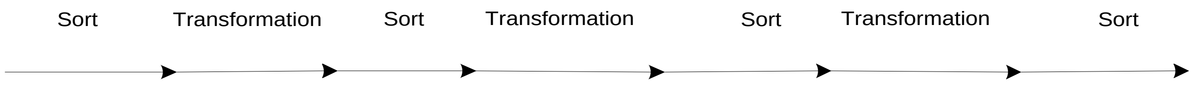


Figure 2.7 Illustration of sequential ordering of sorting and transformation in transvections (adapted from Alderson, 1965, p. 90).

The concept of transvection is an appropriate analytical tool for the analysis of product recovery activities because Alderson (1965) made certain associations with these kinds of business networks. In the original framing of the concept, he stated that at each branching point, where lines in a network for the delivery of the product diverge from the perspective of a seller of used goods, there may be *waste* or *by-products* to be evaluated. *Waste* may carry a cost penalty for disposal, while by-products may contribute some revenue to the main stream. Furthermore, he suggested that goods have to be sorted in preparation for manufacturing processes in order to minimise the expensive and unnecessary production of discards and waste materials (ibid.).

The interlinked forward and reverse physical flows, and the handling of waste from production, are some of the essential elements of product recovery in business networks. This study primarily concerns objects that are discarded after disposal by an end user. This situation takes place after the execution of the original transvection from raw materials in the state of nature to an end user, as portrayed by Alderson (1965). Thus, this thesis takes its point of departure in the concept of extended supply chains (Fleischmann et al., 2005) or, in other words, *extended transvections*, as the efficiency of recovery and reverse logistics operations depends on how end users organise product recovery in collaboration with collectors and reprocessing companies (Flygansvaer, 2006; Krikke et al., 2013; Yang et al., 2013; Zhang et al., 2014). Original raw materials and other specifications that are part of the products in the possession of an end user have an influence in determining which paths these items will take after their disposal. Consequently, it is important to consider the link between transvections, from raw materials to end users and post-use transvections.

An additional connection between organising product recovery and transvections concerns the collection activity, which is regarded as a crucial process for ensuring continuous and efficient supply. Alderson and Martin (1965) described the efficient planning of the collection activity of parcels, which are later delivered to a minor consolidation centre, as an example.

Moreover, transvections include the creation of form utility, which is well adapted for the study of multiple reprocessing activities, such as recycling, that alter the physical shape of an object. To sum up, in any transvection, sorts and transformations must alternate. In other words, a sort always occurs between any two transformations (Alderson, 1965). These two terms (sorts and transformations), will now be explained in more detail.

Transformations

A transformation is a change in the physical form of a product, or in its location in time and place, which is expected to increase its value (ibid.). In other words, transformation adds utilities of form (such as wrapping, fabrication, repair, recycling) place (transportation), and time (such as storage, credit). At a specific point in time, a product can be considered a bundle of various types of utilities that are not easily separated. Alderson (1957) noted a fallacy in breaking utility down into separate aspects, since it is an all-or-nothing proposition. For example, the form utility of an item in terms of its specifications is highly significant for determining the reprocessing option, and consequently for transformations in place and time. Products with factors that shorten sales life cycles, such as technical specifications of models in the electronics industry for which prices go down rapidly, require responsive reverse supply chains, as unnecessary delays cause monetary value to erode (Blackburn et al., 2004; Krikke et al., 2013). This, in turn, affects the choice of reprocessing alternatives.

Remanufacturing and other reprocessing activities represent a transformation or change in *form* utility of an item, such as when a new or used component is disassembled, cleaned and reassembled into an object. Yet another kind of form transformation is performed by retailers of used or refurbished products, who can alter the total PC package by adding buyer-adapted software suites, monitors, and new or refurbished components. Moreover, a dealer may provide installation, maintenance and repair services (Alderson, 1957), which is also the case with companies involved in distribution of used or refurbished products.

Further along the network, logistics service providers can be utilised by dealers to transport these products to end users by transforming the location of objects. These transformation processes change the geographical locations of objects between disposers and reprocessors or end users. Thus, *place utility* is mainly associated with shipment, which is performed in order to overcome *discrepancy in space*. In addition, creation of *place utility* involves offering the goods to customers at close proximity, in order to cut down the distance (ibid.). This can be done by locating remanufacturing plants in suitable geographical locations, or by establishing inventories of used or refurbished products by having intermediaries in several countries.

Time utility can be created by intermediaries through such transformations as storage. The essence of time utility is *'to be able to obtain the article at once instead of waiting'* (ibid., p. 215). When goods are placed into an inventory of items that are about to be recycled, they are transformed in time as collection and reprocessing could be separated temporally due to different operating ratios. This temporal distance refers to *discrepancy in time*, which can also be bridged by credit. Credit enables buyers to start utilising reconditioned equipment before they are required to pay the full amount in cash. Furthermore, retailers and wholesalers transform objects and create time utility by holding inventory of products available to be drawn upon by buyers.

Transformation of identity between retailers and buyers, for instance, refers to changes in ownership or operating control of products. Each of these buyers represents an *identity* towards which sequential activity interdependencies throughout a transvection have to be established. Such activities need to be coordinated in advance through exchanges of information about qualitative and quantitative properties or object classes , such as in orders, confirmations and delivery plans between organisations (Dubois et al., 1999). Plans regarding qualitative object classes of inputs and outputs must be matched so that division of labour between firms proceeds as efficiently as possible. Inter-firm differences between quantitative input and output ratios can be handled by intermediaries that break up bulk products, or buffer products in order to bridge this *discrepancy in quantity* (Rosenbloom, 1995).

To summarise, transformation in form is usually achieved in product recovery arrangements via repair, refurbishing and recycling. In addition to form utility, time, place, and identity, utilities are created by means of transformations along differentiated paths that used goods and materials take on their way to secondary end users. Between each transformation, sorting has to be performed in order to enable decisions to be made regarding transformation inputs and outputs, so that transformations in time, place, form and identity can be carried out in an orderly manner. The concept of sorting will be explored in detail below.

Sorts

'Sorting is reclassification, and involves the creation of subsets from a set, or of a set from subsets' (Alderson, 1965, p. 49). This classification is always related to an already-existing collection. Sorting is the decisional aspect of the business process, whether seen from the standpoint of the supplier/seller or the purchaser/user. There are two main kinds of sorting, *assignment and selection*. Assignment represents the seller's or sender's perspective as they assign items to classes that are to be transformed in different ways thereafter. Selection is done by a buying/receiving organisation and/or an individual, who selects an object to be included in their assortment based on what their assortment already contains.

Sorting can be applied to goods, people and information. An example of information sorting is the sorting of orders. The larger the size of a customer's order and the more standardised order specifications are, the lower the ratio of sales to the fixed costs of billing and customer contact. Sorting of, or searching for, information must precede the sorting of goods and people. The function of searching is to locate objects that belong to specified classes. For instance, real estate parcels may be sorted into residential and commercial classes and assigned to separate salesmen for different periods of time. Sorting may also relate to operations, for example distinctive promotional methods for sales of recycled materials or refurbished objects. Internal customer segmentation is a form of sorting (ibid.), and can classify industrial buyers and users of second-hand products by industry, by location or by type of products consumed.

To exemplify the process in connection with product recovery, a disposer assigns objects to be placed in a container for disposal. A reason for disposal may be that these goods do not have any use value for this consumer. To guide sorts and transformations, a number of classifications are established for metals, plastics, paper and other materials in the waste disposal room. A waste management company assigns material fractions to trucks for economical transportation. A recycling company may in turn select certain materials, such as steel, from several localities, including the raw materials from mining, thereby initiating the processing. Then, the steel-producing company may assign various products in different batches adapted to one or several truck or container loads. Selection can be done later on in the process, such as when a car manufacturer buys the parts necessary for the vehicle assembly process.

This phenomenon is called the *discrepancy of assortments*, and relates to the most convenient or constructive association of goods at each stage in the physical flow of merchandise (Alderson, 1957). Differences in applied technologies at successive levels in product recovery processes are the basis of this association. Therefore, used products and recycled materials can be jointly transported because of similar physical handling characteristics and common origins and destinations.

With regard to the product recovery context for used goods, processes of grading, classification and testing of items are treated as crucial activities for the determination of paths for products, components and materials in reverse logistics, closed loop supply chain management, and product recovery literature (Guide and van Wassenhove, 2002; Flapper et al., 2005; Zhou and Piramuthu, 2013). The activity of classification of product properties is also decisive for the selection of multiple recovery options. Hayek (1952, 1982) stressed the importance of classification as a knowledge problem that consists of identifying properties (‘What are goods?’) and prices (‘How scarce or valuable are they?’). The next section presents a discussion on the importance of sorting with regard to uniformity and diversity of transformation outputs, as well as how sorting affects temporal organisation of activities in line with the principles of postponement and speculation.

Crossing and differentiation points

In order to manage similarity and diversity, actors must distinguish objects by certain features in order to qualify them as belonging to distinctive or similar groups at certain decision points in an inter-organisational network. For example, the standards and properties for identifying the size of used monitors are aids in this process. Therefore, organising of activities in a temporal and spatial sense is supported by classification systems whose purpose is to differentiate and redifferentiate objects at *crossing and differentiation points*. These two notions are described below.

Crossing points

Firms try to exploit economies of scale in order to minimise the costs of their operations. This is another way of saying that classifications are established to create and capture *uniformities* among objects that can be transformed in a likewise fashion. Hulthén (2002) analysed this by developing the concept of *crossing points*, which are special types of transformation resources, such as load carriers or machinery, wherein different transvections jointly utilise the same transformation resource. A crossing point is used to generate uniformity in time, place, form, and/or identity object classes so as to achieve economies of scale.

There are uniformities in form (such as the same recycling machines), time (the same storage space in a warehouse or truck), identity (the same organisation, organisational unit or specific counterpart), and place (the same object/load carrier with the same geographical pick-up or delivery location), and corresponding crossing points (Hulthén, 2002). In order to achieve economies of scale in operations, a number of uniformities can be utilised in the network. Thus, used or recycled objects in standardised pallets that have different technical specifications can be stored in the same warehouse, regardless of whether they are new or used.

In a similar vein, pallets, trailers, containers and business units are also crossing points, as the uniformities of objects in terms of time, form, place, and identity can be utilised to enhance economies of scale. Another example of a crossing point is a hub or terminal in a transportation network, to which objects with the same destination can be jointly assigned. A hub can be used for the collection and inventory holding of load carriers of different kinds of products that are transformed in time during storage, and then sorted by the time and place dimension to facilities for recycling, remanufacturing and refurbishing. Firms can assign used objects to trucks and facilities of logistics service providers, who can deliver the objects to alternative locations by creating similarities in crossing points, such as standardised pallets and trucks headed for the same geographical area at the same time. Information about weight, volume, delivery/pick up address and date is thus crucial to aid in the handling of parallel and sequential dependence between activities from many collection and delivery sites.

Crossing points are used for transformations in product recovery arrangements that possess parallel dependence. Parallel dependence and activity similarities in product recovery include use of the same crossing points in terms of testing equipment, refurbishing capabilities, transportation facilities and inventories. When it comes to crossing points related to form utility, it is crucial that similarities in form transformations – that is, reprocessing – are generated. By identifying uniformity of form among the classes of object sets, the products become assigned to appropriate resources for transformation in form.

This is done for the sake of temporal economies of scale in transformations. This exploitation of parallel dependence or activity similarity in transformations is done at crossing points such as collection centres or terminals. Such facilities can be used for the inventory holding of pallets containing many kinds of products. In such a case, these palletized products are transformed in time in order to be sorted by the time and place dimension to a certain destination later on. Items in transportation are classed, packaged, and treated similarly or differently according to several classes with respect to weight and overall dimensions. Hence, objects that are quite different in terms of use value may be classified similarly during transportation according to weight, physical characteristics, overall dimensions, destination, date of possession, and type of installation.

Differentiation points

Insanic (2012) indicated the economic influence of appropriate arrangement of the points where the transvections diverge towards alternative recovery options among and in transvections. More precisely, actors arrange and locate *differentiation points* temporally and spatially in the network, where they sort products in time, form, place, and identity so that products become differentiated. In this thesis, the term ‘differentiation point’ is used in order to distinguish this concept from ‘decoupling points’, which have been discussed in literature on supply chain management, implicitly or explicitly, by, for example, Mason-Jones and Towill (1999), Pagh and Cooper (1998), and Sjoerd and Romme (1992), and in Closed Loop Supply Chain Management literature by Wikner and Tang (2008). The primary concern of these authors is the temporal coordination of activities, rather than an inquiry into how structured information exchange about an object’s dimensions affects the direction and interrelatedness of transvections. That is to say that decoupling points demarcate ‘push’ (speculative) and ‘pull’ (end user-order-driven) activities with regard to the end user, and do not take into account intermediate actors or the object properties that are classified into time, place, form, and identity dimensions. However, the reasoning regarding the appropriate location of informational and material decoupling points is included in the frame of reference here.

There are two types of decoupling points around which supply chains, and thereby individual transvections, are constructed: the materials decoupling point and the information decoupling point (Mason-Jones and Towill, 1999). The materials decoupling point is formally defined as *‘the point in the product axis to which the customer’s order penetrates. It is where order driven and the forecast driven activities meet. As a rule, the decoupling point coincides with an important stock point – in control terms a main stock point – from which the customer has to be supplied’* (Sjoerd and Romme, 1992, p. 37). By altering the position of the material decoupling point a number of postponement strategies can be put into effect, from providing highly customised or counterpart-adapted products (full postponement) through to providing a standard product with low demand uncertainty (full speculation) (Pagh and Cooper, 1998). Full postponement moves product differentiation close to the buyer or receiver via an inventory of generic products that can be customised at the material decoupling point (ibid.).

Since information exchange has a significant influence on activities related to material flows, the information decoupling point is defined by Mason-Jones and Towill (1999) as *'The point in the information pipeline to which the marketplace order data penetrates without modification. It is here where market driven and forecast driven information flows meet.'* Traditionally, the materials decoupling point and the information decoupling point were placed at the same position, which led to point-to-point movements of goods between organisations (ibid.). The authors argued that the problem of matching supply and demand, caused by information distortion and delay, may be solved by moving the information decoupling point as far upstream as possible. In this manner, informed decisions are made at a much earlier point in time.

I introduce the term *information differentiation point*, or the point in time at which the data about object dimensions defined by the time, place, form, and identity object classes becomes fixed and certain with regard to another actor or a consignee. The information differentiation point is the point in time and place when and where the order is finally placed. It is when object properties become fixed in terms of selections and assignments of objects with regard to an intermediate actor or an end user, entailing several points in the network rather than just one, where information has to be adapted to each member of the network. It is when and where informational transfer of possession or ownership rights is finalized. From this moment on, activities that are performed on objects become closely complementary if the valorisation of all of the object's properties is related to an end user. Otherwise, the activities are complementary, involving a sequential interdependence, which is characteristic of a full speculation strategy.

Depending on the provision and exchange of information from the information differentiation point through inter-organisational and intra-organisational classification systems, the *materials differentiation point*, in terms of the object's time, place, form, and intermediate identity features, can be switched. The materials differentiation point is the point in time and place at which the assignment/selection of an object towards a specific actor occurs in a physical sense. Therefore, there can be several material differentiation points in transvections, as actors who are not end users can be specialised in various inputs and outputs of objects, requiring alternation of the direction of the physical flow. Apart from defining the point in the physical flow, the materials differentiation point is concerned with the point in time and place at which assignment and selection, in an immediate physical sense, is complete.

The existence of the information differentiation point at an earlier point in time than the actual transformations and sortings take place enables grouping of similar objects and their joint assignment to the same transformation resource before this happens on the shop floor, for example. The information differentiation point refers to the completion of an order placement; that is, when and where the transfer of possession, as in operating control or title, is finalised. At the information differentiation point, the value of the identity dimension or object class becomes changed. It is here that complementarity of activities that are performed on objects is established. The materials differentiation point, on the other hand, is related to the physical transfer of an object to an actor. Differentiation points are therefore closely associated with the identity class of a single object and sequential interdependence, while the crossing points are connected to the identification of uniformities with regard to quantitative terms, as in the reaping of economies of scale in parallel interdependencies.

Besides planning crossing points, the actors can arrange materials differentiation points in advance because they can expect goods to have certain values in form, time, place, and identity dimensions when the material is physically handled. In terms of activity interdependencies, the actors in the network have handled uncertainty via a prediction and forecasting of supply and demand on an aggregated level, before the actual handling of materials begins. Therefore, they are able to plan for the efficient handling and combining of activity similarities and complementarities.

When it comes to the product recovery context, depending on various classes of objects, such as appearance, technical specifications, state of the product, and price, an item may be *differentiated* in order to be recycled or refurbished. Various organisations are specialised in these inputs, based on the properties or specifications of raw materials of which they are made. This section on organising product recovery in activity patterns between organisations will end in a discussion on research issues related to, among other things, crossing and differentiation points.

2.3.4 Research issues

Organising of activities means coordinating collection, product recovery options, and distribution in order to achieve a balance between economies of scale and diversity. Activity patterns feature specific mixtures of similarity/diversity and complementarity/close complementarity. Uniformities in transvections are generated in form, time, place, and identity dimensions for the sake of economies of scale or similarities among activities. Temporal coordination of activities in product recovery and its connection to risk and uncertainty can be analysed using principles of postponement and speculation. Product recovery contexts are usually associated with uncertainties of supply in timing, volume, type and state of the product.

The exploration of organising product recovery in the activity layer is based on the concept of transvection. The central research issue here is identifying transvections that represent various forms of product recovery options (from reuse to recycling). The sorting and transformation activities in these transvections are then analysed with regard to the occurrence of:

- Parallel dependencies and similarities.
- Sequential dependencies and complementarities.
- Postponement versus speculation.
- Uncertainties in time, place, form, and identity.
- Crossing and differentiation points.

Besides providing a framework for analysing activities in industrial networks, the ARA model (Håkansson and Snehota, 1995) emphasises the interrelatedness between activities and resources. Central features of resources and analytical tools for the analysis of the resource layer of the ARA model are discussed in the next part of this chapter.

2.4 Organising product recovery in resource constellations

The Industrial Network Approach takes a holistic perspective on resources as it can be applied to analyse resource interaction across multiple inter-organisational boundaries (Håkansson et al., 2009). Heterogeneity and adaptations are central features of resources in the models and frameworks of the Industrial Network Approach (ibid.). These main properties of resources, together with analytical tools and issues related to organising the resource constellations in networks, are discussed in this part of the frame of reference. This section is concerned with the resource dimension in business networks, and ends with a discussion about organisation of resources in product recovery and research issues.

2.4.1 Resources in product recovery

Resources are crucial since they contribute to the efficient undertaking of activities in product recovery arrangements. Typical activities and processes in reverse logistics are acquisition, collection, logistics, classification/inspection, reprocessing (for example, recycling), and distribution to other organisations that perform activities on products in their facilities. These facilities could be trucks, trains, pallets, containers, recycling machines, or warehouses.

First of all, the product itself is a resource that needs to be collected, remanufactured or recycled, and distributed. Knowledge about the state of the product and its general status is a precondition for accurate direction, and therefore transformations, in the movement of goods towards suitable facilities for dismantling, testing and reassembly. For instance, waste paper needs to be de-inked for paper production, while used computers need to be tested, and disassembled into parts appropriate for the production of raw materials.

During disposal and acquisition, both disposers and the organisations that are involved in product recovery options must be capable of classifing products. As Jahre (1995) points out, disposers must possess some type of knowledge in order to classify products. This is due to the fact that they always perform some type of separation of goods at their facilities (ibid.). When buying and selling used and/or reprocessed products, sales and purchasing expertise regarding the product in question is essential in order to balance supply with demand.

Collection and physical distribution management require resources. Examples of these resources are enterprise planning systems utilised for information exchange, and organising and route planning of physical resources that are involved in distribution processes. In her study on coordinated action in reverse distribution systems, Flygansvaer (2006) recognised a set of different kinds of physical resources. Thus, cages and dismantling facilities are regarded as more context-specific than other resources for more general purposes, such as standardised containers and transportation vehicles, which are utilised in these logistics networks. The primary function of these resources refers to time and place transformations in transvections.

Examples of resources that are used for sorting of objects in transvections include testing and diagnostic equipment or software, and sensors. These productivity-enhancing resources store data about the use and status of products so as to enable the quick comparison and identification of a product’s characteristics (Flapper et al., 2005). Toffel (2004) and Giovanni and Zaccour (2014) highlighted the importance of knowledge involved in product recovery, such as skills and expertise regarding collection, repair, disassembly and product design. Winkler (2011) pointed out the significance of reverse logistics skills. Capabilities in reverse logistics and various product recovery options possessed by separate actors are important resources in order to perform product recovery activities in networks (Giovanni and Zaccour, 2014). In this manner, the tacit dimension of know-how is of great significance in the product recovery arrangements of business networks (Toffel, 2004; Krikke et al., 2013). In many cases, reprocessing firms, including those that have access to codified Original Equipment Manufacturers’ specifications, have to conduct a study of the product in order to understand how to disassemble and reassemble it efficiently (Toffel, 2004). Resource adaptations within product recovery research and resources in general have not been sufficiently investigated, and very little research has been conducted on resourcing and resource utilisation (Srivastava, 2008; Ilgin and Gupta, 2010; Tuzkaya et al., 2011).

In order to elucidate the existence of links between forward and reverse physical flows, Fleischmann et al. (2001) and Winkler (2011) argued that reverse logistics networks are built on top of existing logistics structures. Integration and creation of sustainable closed loop supply networks is based on cooperative efforts in research and development (ibid.). This interaction between forward and reverse logistics structures has also been demonstrated by Håkansson and Waluszewski (2002) in their analysis of such arrangements. Through application of the Industrial Network Approach on technological development within these networks, they showed that a waste paper recycling solution had to fit into an activated heterogeneous resource structure adapted to the use of primary paper fibre. As the theoretical foundation of this thesis is the Industrial Network Approach, some of the basic assumptions regarding resources in this theoretical tradition are depicted in the following part of this chapter.

2.4.2 Central features of resources

The ARA model highlights the significance of adaptations between resources that are considered heterogeneous (Håkansson et al., 2009). Heterogeneity and adaptations are two of the central features of the Industrial Network Approach, which are the topics presented in the following part of the chapter, concerned with the resource layer of the ARA framework.

Resource heterogeneity

Resource heterogeneity is put forward as perhaps the most central assumption in the Industrial Network Approach (Holmen, 2001; Håkansson et al., 2009). During an investigation aimed at explaining firm growth, Penrose (1959) declared that the value of resources is dependent on the services they can render. Resources do not therefore have a fixed homogeneous utility. The expansion of firms is largely based on opportunities to use their existing productive resources more efficiently than they are currently being used (ibid.). She stated that *‘The services yielded by resources are a function of the way in which they are used – exactly the same resource when used for different purposes or in different ways and in combination with different types or amounts of other resources provides a different service or set of services’* (ibid., p. 25). Furthermore, *‘It is the heterogeneity … of the productive services available or potentially available from its resources that gives each firm its unique character’* (ibid., p. 75, 77).

It is not only through internal usage or combination of resources that firms may gain benefits. The value of a resource is dependent on how it is used, combined with or related to other resources in an inter-organisational network setting (Håkansson et al., 2009). An element needs to have a known or potential use in order to be defined as a resource (Håkansson and Snehota, 1995). Hence, resource heterogeneity assumption stresses the importance of knowledge about resources themselves, and about which combinations might achieve desired outcomes within the firms, and between collaborating companies (ibid.). In some contexts, used newspapers and packaging products are regarded as waste, while in others, these items might be useful as ‘green’ material for paper production (Håkansson et al., 2009).

In the ARA model (see Figure 2.3), a company’s assets are classified as collections of resources. From a network perspective, a single company’s resource collection belongs to a resource constellation that is embedded in a business network (Håkansson and Snehota, 1995). Interaction processes between actors, activities and resources affect all these resources by creating and/or forming them and their features (Jahre et al., 2006). The pattern of interactions that form the relationship requires resource adaptations over time (Håkansson and Snehota, 1995). Adaptations could involve organisational resources such as organisational units, and knowledge and physical resources such as products, facilities, and machinery. Some of these inter-organisational adaptations take place due to the fact that no company has sufficient assets to satisfy the requirements of every potential customer (Ford et al., 2003). In resource constellations of business networks, a firm's performance depends on adaptations between the skills and technologies of suppliers, distributors, customers, and sometimes even competitors (ibid.). Resource adaptations are discussed in the next section of this chapter.

Resource adaptations

Inter-organisational relationships require resource adaptations across companies (Håkansson and Snehota, 1995). A resource constellation within a business network consists of several resource collections that are controlled by many organisational units. Thus, resource collections of a number of companies are connected to each other. Within business relationships that span multiple company boundaries, the patterns of interactions that form inter-organisational relationships create adaptations over time. As the development of inter-organisational resource adaptations proceeds, the resource constellation of a network emerges (ibid.).

Adaptations are made to increase or decrease the variety of solutions (Håkansson et al., 2009). Standardisations create economic benefits because they reduce variety. By homogenising working procedures and solutions to problems, companies in inter-organisational contexts can reduce variety. Offerings, reprocessing and production processes are standardised to reduce the need for continuous adjustments. Some resources, such as products, may be related to other resources, such as production equipment, which is crucial for standardisation. Resource adaptations can also be carried out in order to increase variety, which is exemplified in specific adjustments made toward certain counterparts. Huang and Su (2013, p. 626) claimed that: '*Although increasing the number of product types can better satisfy diverse customer needs, complexity in the product recycling, remanufacturing, and resale processes may erode a firm's overall profits.'* Thus, these products become part of unique resource combinations in both forward and reverse supply networks, with their own particular tensions and adaptations.

Resource adaptations create tension in some dimensions of business networks, while creating benefits in others (Håkansson et al., 2009). Development patterns of resources may be contradictory in different combinations where resources need to fit. A consequence of this resource issue is that every resource has features that stem from previous interactions with other resources. Håkansson et al. stated that: *'The more adaptations to the other resources in a specific combination, the more difficult it will be to use the individual resource efficiently in other resource combinations with different characteristics'* (ibid., p. 86). When a resource interacts with other resources, it is given some specific characteristics, which are referred to as features and imprints (Håkansson and Waluszewski, 2002). As illustrated by the authors in an arrangement where waste paper was collected, classified and distributed to a paper mill, there are combinations of physical and organisational resources that have to be interrelated. At the same time, contradictory resource interfaces are created (ibid.). For example, products in the electronics industry are more adapted to forward logistics networks than to reverse distribution networks (Jahre et al., 2006). Having explored resource adaptations, we will turn to analytical tools that are to be employed in the examination of these adaptations, in relation to organising product recovery.

2.4.3 Analytical tools for resources

This part of the chapter presents analytical tools for the exploration of the resource layer in business networks. Resource constellations in this thesis will be analysed by applying a framework known as the 4R model (Håkansson and Waluszewski, 2002), in combination with the concept of *object* (Hulthén, 2002), which was used to analyse transvections.

The 4R model – the model of four resource entities

The 4R model was developed by Håkansson and Waluszewski (2002), and deals with the technological development of resources. In particular, what is more relevant to, or suitable for, this thesis is the fact that one of their case studies was based on what is essentially an analysis of how a resource changes through its association with other resources in a reverse logistics network for collecting, recycling and distribution of waste paper.

Moreover, the 4R model has been utilised by Jahre et al. (2006) in a case study of resource combining through resource interaction in a network involving a logistics set-up for recycling. This suggests that the 4R model will also be appropriate for the study of organising product recovery arrangements in this thesis. More precisely, the 4R model is suitable for an analysis of the changes to a product that is recovered in a product recovery network, and the product's connections to other resources. These connections between resources are identified as interfaces in the 4R model. Each resource has a specific interface in its relation to other resources, and these interfaces are embedded into a larger pattern of related interfaces (ibid.). Resource interfaces are defined as the *contact points*, which specify, in a qualitative and quantitative sense, how and to what extent two resources affect each other (Håkansson and Waluszewski, 2002). Interfaces between physical resources are determined by functional and technical conditions, while organizational resources are influenced by their administrative and social characteristics (Jahre et al., 2006).

Håkansson and Waluszewski (2002) developed a tool for analysing resource development by classifying resources into four elements. *Products* and *facilities* are two such resource types, and are physical in character. The other two kinds of resources in the framework are of an organisational nature, and these are labelled *organisational relationships* and *organisational units*. Four types of resources can therefore be distinguished in the 4R model, as follows (Håkansson et al., 2009):

- *Products*. These resources are manufactured, distributed, used or reprocessed in the facilities in question. They are combinations of physical resources that can be moved around, and may relate to several structures.
- *Production facilities.* Facilities are resources that have a more permanent nature compared to products. They can include materials handling equipment, load carriers, numerous means of transportation, and tools such as machinery or information systems utilised in economic and/or physical transformation of products. Facilities are vital for other distinctive and succeeding resource combinations.
- *Organisational units.* Knowledge, skills and experience are resources in organisations, individuals or groups and groups of business units that are required to handle particular resource combinations.
- *Organisational relationships.* Organisational relationships, which are closely related to business relationships, are assets that bind together all of the other resources of a company and convert them into something that is of economic value. Relationships cross company boundaries, routines, and procedures.

It may be claimed that resource adaptations involve both organisational and physical resources, and that one type of adaptation impacts on the other (Jahre et al., 2006). The relatedness created between physical resources relies on organisational resources. The interfaces between a product and an organisational relationship or unit may involve an assessment of the product's share of the revenues within the unit and relationship, or the organisational unit's and the relationship's share of the product's revenues. With regard to facilities and organizational resources, an analysis of the relationship's share of the capacity of a particular facility, and vice versa, can be performed in order to investigate such interfaces. In other words, by applying the 4R model it is possible to study interfaces between the same and different kinds of assets in resource constellations. Resource interfaces are central in the 4R model, as one of the aspects of adaptation relates to changing the interfaces between resources, as in the case of a focal product and its relations to other resources (ibid.).

Products – a resource entity in the 4R model

Products are an essential part of the 4R model, as their attributes and nature largely determine the features of facilities (Jahre et al., 2006). In the 4R model, products are referred to as a type of physical resources that are manufactured, distributed, and used at these facilities. In a product recovery context, products are collected, reprocessed and redistributed to new users. Selection of product recovery options and re-entry into resource constellations of forward physical flows depends on the features of the product (Khor and Udin, 2013).

In order to connect the 4R model to transvections, and the activity layer of the ARA model, the concept of the *object* (Hulthén, 2002) is introduced here instead of 'products'. Hulthén classified products as objects with form, time, place, and identity features, which are sorted and transformed in transvections (ibid.). Furthermore, she used the concept of the object in order to study resources involved in transvections, by relating the object to the resource dimension of the Industrial Network Approach. Therefore, the focal resource in this study is the object. Moreover, this starting point was chosen because this study is about recovering products, and directing them towards multiple resources related to product recovery options. An additional reason for this choice of the product as a focal resource is the fact that in transvections the centre of attention is the product. Hence, in the following three sections objects are regarded as products in the 4R model, while organisational units and organisational relationships are treated as forces that systematically organise facilities and objects through interaction processes.

In this study, objects are utilised to analyse product recovery in accordance with Hulthén's (2002) framework, which connects activity aspects of transvection to the resource layer of the Industrial Network Approach. She held that objects change features when they enter transformations, and that these objects can be used as input in other transformation activities. In addition, this starting point is taken because this study is about recovering products and how they are directed towards different types of reprocessing resources. 'Objects' also represents a more inclusive terminology, as products may be regarded as something fixed, whereas in product recovery contexts, substantial changes of object characteristics might occur. For example, end-of-use products could be transported to a secondary user in the same state as they were originally purchased, or become raw materials. The term 'object' captures this heterogeneity in a more suitable manner than 'product' does.

This heterogeneity is reflected in the diversity of object classifications in various settings. Hayek (1952) and Alderson (1965) clarify that the end user classifies objects and interfaces with other resources in terms of the 4R model in accordance with their purpose for utilisation, without taking any technical details into consideration (such as deep or detailed knowledge of the physical attributes, which are more relevant in the product development or manufacturing combinations and constellations). Furthermore, the technology of production has to be related to the resource constellations of reverse physical flows, as in design for disassembly and accessibility of reusable content (Khor and Udin, 2013). This design simplifies the inspection and extraction of reusable parts, modules, and materials when these resources are combined and recombined by the product recovery firms. That is to say, modular design reduces the costs of remanufacturing (Kristianto and Helo, 2014).

Chamberlin (1946) put the process of qualification–requalification, or resource combining from the perspective of the 4R model, as one of the most central aspects of the dynamics of business. Hence, according to Chamberlin (1946), the qualities that allow an object to be defined and positioned in relation to other products are not established once and for all. This is because they have the strange characteristic of being constituents of the good, but nonetheless reconfigurable by means of resource combining. The list of attributes is open, and could contain technical as well as other properties, resources and interfaces, such as particular sales or buying conditions in organisational relationships, location of organisational units, and personal relations between the salesperson and customers.

For example, transportation companies establish object features and interfaces – that is, weight, volume, dimensions, and collection/delivery dates and addresses – without any necessary deeper product knowledge in other form dimensions. It is the classifications in the interfaces that both connect and separate different contexts, since the information needed for an actor-specific resource combining has to be adapted to the requirements of that actor by its partner. In order to initiate any kind of reprocessing, there has to be an organisational relationship that enables information exchange through the interfaces. These interfaces provide access to the resources of knowledge, machinery, facilities and organisational relationships of companies involved in product recovery. This means that there is a division of labour and specialisation by object inputs and outputs (Alderson, 1957; Mahmoudzadeh et al., 2013) of activities within and among different facilities belonging to a range of actors. *'Goods are associated at the manufacturing level because they can be made on the same equipment or in the same plant … they are associated at the wholesale level because of similarities among trade customers and requirements for shipment and storage'* (Alderson, 1965, p. 33). Supported by this logic, Hulthén (2002) argues that it is important to create and identify uniformity of objects in time, form, place, and identity, so that they can share the same facilities. Creation and capturing of economies of scale are generated by means of classifications that assign objects with some features in common to facilities for reprocessing and distribution.

Facilities – a resource entity in the 4R model

Facilities change products when these resources interact. A reprocessing plant, or a specific machine or software for inspection of a certain kind of product, is regarded as a facility. Hence, interrelated products and facilities are usually mutually adapted. On the other hand, facilities such as pallets or containers could be used for different purposes, such as for transportation of various kinds of goods. Facilities can be viewed with varying perspectives and aggregate levels of analysis. A single truck, transporting used goods, is utilised for the transformation in place; however, from a greater perspective, several trucks that deliver a certain type of raw materials to a testing facility are used in collection and logistics.

With regard to product recovery structures, all kinds of resources, including collective resources such as infrastructure, can be used to perform sorting and transformation in time, place, identity and form. Machines and human labour are used in form transformations, such as recycling, disassembly or remanufacturing. Inventories are used for time transformations of used, refurbished or recycled physical items, while databases are used for time transformations of information. An information system or software is used to vicariously or indirectly sort and transform the necessary information tied to a certain used or remanufactured product according to certain rules, which determine the type of resource that should be utilised in the next sequence.

Testing and classification equipment are facilities that are used for the sorting of products according to predetermined rules. Diagnostic apparatus, sensors, chips, machines, and telecommunications technology vicariously sort or search for either information or goods, on behalf of people. A purchaser or an administrative salesperson may only require an article number, which is a type of a class, to order thousands products of the same type when the automatic reminder information indicates that the inventory level has reached the minimum level. Hence, the quantity dimension of an object has to be known in order for resource combining to proceed. The information system is programmed to search according to classification rules for time, form, identity, quantity and place when a user wants to locate a desired refurbished product. This is also an example of how resources are used to automate, speed up, and rationalise previously manual activities of order-quantity calculations, which itself is a rule which states that the inventory required goes up in proportion to the square root of sales.

Alderson and Martin (1965) argued that the situation of adding and removing sorts and transformations is dynamic, because of changing technologies in related facilities. For example, development in mechanical sorting equipment (ibid.) or informational sorting and transformation technology, such as vicarious search engines and Electronic Data Interchange[17] systems, has enabled sorts to lead to greater efficiency. The implementation of an RFID system leads to enhanced information about returns and better supply predictability (Kim and Glock, 2014) while, for example, SpectraCode's Polymer Identification System and other comparable technology improves disassembly productivity by quickly identifying plastic polymers in both electronics and automotive products. RFID technology is valuable in optimised determination of an object's quality status and selection of a product recovery option, which reduces the overall operational costs of sorting (Zhou and Piramuthu, 2013).

Facilities are, for instance, needed to identify and specify a used car's road-holding features, engine capacity and fuel consumption, as well as the resistance of paint to corrosion and the vehicle's delivery time. Measurement instruments are able to describe the technical information required for repair, which are then translated into classes of documents, such as those guaranteeing traceability. All of the classes in the instruments and documents need to be developed and created in organisational relationships. This involves agreeing on which

[17] An electronic information exchange system that allows automatic transmission of standardised and structured data between actors.

characteristics or classes of products should be taken into consideration, and the values given to each of them within classifications and information systems. By using advanced information systems and dedicated facilities, third-party reverse logistics providers are playing an increasingly strategic role in Closed Loop Supply Chains (Govindan et al., 2012). Access to the classification systems and other facilities for product recovery is provided by relationships between companies, departments, and other types of organisations, which, in turn, are regarded as organisational units in the 4R model.

Organisational units – a resource entity in the 4R model
Organisational units are defined as firms, or parts or agglomerations of firms (Jahre et al., 2006). These units interact in order to create and maintain activity links, resource ties and actor bonds (ibid.). Competencies and capabilities of employees belonging to companies and institutions in networks are examples of resources that are associated with organisational units. Organisational units contribute to collaborative efforts with other business units via the units' resources and experience, and knowledge in closed loop supply networks (Winkler, 2011). Competency for management of physical resources, such as objects, resides within single firms. This concerns the adjustment and development of classification systems, location of crossing points, and material and information differentiation points. Skills relating to performing and coordinating activities, and combining resources – or, to put it in a more simplistic manner, sorting and transforming objects and information about objects, in line with the focus of this study – are partially based in the capacity to act according to both abstract and case-dependent rules. As Brunsson and Jacobsson (2000) remarked, knowledge is often stored in rules, which may be stored in facilities such as information and classification systems.

In addition to this know-how of a more technical nature, organisational units have knowledge of how to handle organisational relationships. In product recovery settings, several types of capabilities are related to organisational units. These capabilities include knowledge in different firms and departments, ranging from the people involved in marketing and purchasing of used products, those managing reverse logistics, and those transporting refurbished goods. All these abilities are elements in complex inter-organisational networks. Furthermore, operational management skills are also essential in the sorting and transformation of used products, components and raw materials, in line with corresponding rules and object classes.

Many companies have unique, tacit knowledge about dismantling and collection processes in their businesses, which makes them a vital reservoir of capabilities (Toffel, 2004; Giovanni and Zaccour, 2014). Callon et al. (2002) stated that the use phase of a product changes the product's attributes due to wear. A second-hand dealer can therefore diagnose problems with a used car, change the certain properties of the product by replacing components, and superimpose the bundle of the object's classes by means of the pricing system. Hence, the ability to modify the list of qualities is a strategic resource, as it is a matter of positioning the good in the space of goods, which comprises all possible dimensions and qualities.

From a network perspective, this product-based knowledge is embedded into the resource constellation of a wider inter-organisational landscape consisting of organisational relationships. Jahre et al. (2006, p. 141) stated that: *'It is the business relationship that influences the interfaces and adaptations between the other types of resources through the activities taking place between the companies, i.e. the provision and use of the resource(s).'* Organisational units connect physical and organisational resources in the network through organisational relationships. Due to the importance of organisational relationships, some of their essential characteristics will now be described.

Organisational relationships – a resource entity in the 4R model

Organisational relationships, which are discussed in depth in the sections concerning the actor layer of the ARA model, are resources because they are utilised in resource combining and recombining. Resource combining takes place in resource constellations of business networks. Moreover, these relationships are frequently tied by resource adaptations that can change the value of specific resource collections and resource constellations within industrial networks (Håkansson et al., 2009). Organisational relationships are essential in business landscapes as they make it possible to develop and use other resources, such as facilities, products, organisational units and other organisational relationships (Jahre et al., 2006). Winkler (2011) argued that win–win relationships and collaborative research and development frameworks between actors create the basis of a sustainable closed loop network.

Organisational relationships play a vital role in connecting resources in a structural and process-oriented or functional sense (Jahre et al., 2006). One role of organisational relationships relates to the way relationships function as bridges within the network, providing existing and potential structural access to resources in other parts of the network. Thus, an intermediary that has a developed relationship with the disposer can face a lower marginal collection cost compared to other actors in the network, since *'it directly informs customers*[18] *about the return policy and explains how the collection procedure works out'* (Giovanni and Zaccour, 2014, p. 34).

An additional function of organisational relationships is their contribution to the changes in values of resources generated in combining processes through the classification systems. In order for resources to be combined in an appropriate manner, they must be related to each other through adaptations between companies in technical, administrative and logistical dimensions (Gadde and Håkansson, 2001). The selection of a Third Party Reverse Logistics Provider depends on matching certain values between the companies, such as the

[18] Disposers.

infrastructure and operational capacity in forward and reverse logistics, as well as the reverse logistics provider's alliances and financial status (Guarnieri et al., 2014). Such inter-organisational adaptations tend to bind the companies together and impose interdependence in product recovery settings. By interacting in organisational relationships, organisational units involved in collection, product recovery options and the distribution of objects develop classification systems in order to organise resource constellations and resource combinations through interfaces.

2.4.4 Research issues

One of the cornerstones of the Industrial Network Approach is the idea of analysing business landscapes through the study of the dynamics of resource combining and recombining. Based on the assumption of resource heterogeneity in networks, the value of a resource is determined by how it is combined with other resources in business networks. Organising actions such as resource combining depend on organisational resources, such as organisational units and relationships. Physical resources are combined with each other, and, in their turn, are combined with organisational resources.

Organisational relationships between firms involved in collection, remanufacturing, recycling and distribution accommodate the resource combining of facilities such as trucks, warehouses, load carriers and information systems. Firms might also combine resources between forward and reverse object flows, as explained by Flapper et al. (2005), and Håkansson and Waluszewski (2002). This is crucial from the resource utilisation perspective so that transformations in such physical flows can share the same facilities and capabilities across organisational units.

The exploration of product recovery in the resource layer is based on the transvections identified in the activity layer. Sorting and transformation in transvections require resources of various types that are continually combined and recombined. The interfaces between the specific object and other resources are central for the recovery of the object. The central research issue here is to analyse the interfaces depicted in Figure 2.8 among resources along the transvection, including:

- Interfaces between the object and other products.
- Interfaces between the object and facilities.
- Interfaces between the object and organisational units.
- Interfaces between the object and organisational relationships.

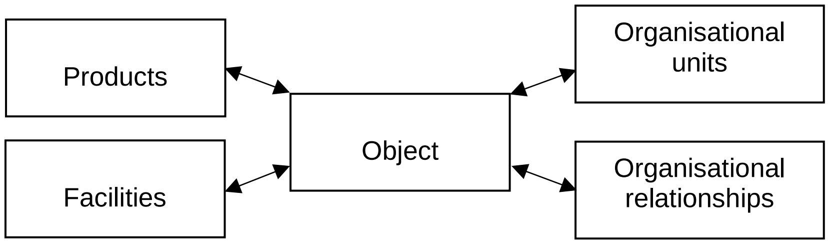


Figure 2.8 The resource interfaces of an object to be recovered (adapted from Jahre et al., 2006, p. 61).

Resource combining and activity coordination influence, and are influenced by, the nature of organisational relationships (Gadde, 2004). These relationships are embedded in webs of actors. The effect that interaction has on organising product recovery will be discussed in the next section.

2.5 Organising product recovery in the web of actors

The third layer of the ARA framework is concerned with the actor layer. This part of the chapter will introduce the actor layer, and how this layer relates to the product recovery context. First, a discussion will be conducted about general aspects of actors in product recovery. These aspects will then be combined with some central features of actors in the Industrial Network Approach. After that, the organising role of actors in product recovery will be described. Finally, as a result of the elaborations with regard to the actor layer of the Activity-Resource-Actor model and its connections to organising product recovery in the web of actors, the research issues will be outlined.

2.5.1 Actors in product recovery

Actors both affect, and are affected by, activities and resources in networks (Håkansson et al., 2009). Interaction in a wider web of actors enables activity coordination and resource combining. This section is therefore based on previous elaborations on activities (section 2.3) and resources (section 2.4) associated with product recovery in networks.

There are several classifications of actors involved in product recovery arrangements in business networks. Most actor classifications are process oriented (e.g. Thierry et al., 1995; Fleischmann et al., 2000; de Brito and Dekker, 2003; White et al., 2003; Krikke et al., 2004; Srivastava, 2007; Guide and van Wassenhove, 2009; Jamshidi, 2011). This activity orientation defines actors by identifying the activities they perform in product recovery settings (de Brito and Dekker, 2003). In this regard, actors that are involved in forward physical flows may perform a function or activity in reverse physical flows. That is to say, firms such as manufacturers or intermediaries can assume the role of collectors or reprocessors in reverse goods flows (Faccio et al., 2014). Within the Industrial Network Approachresearch tradition, Jahre et al. (2006) acknowledged interactions between actor roles in resource constellations of forward and reverse physical flows. Logistics service providers usually relate existing activity structures of new products to the activity structures associated with used items (ibid.).

Jahre et al. (2006) labelled actors in accordance with this activity dimension by characterising them as customers, collectors, reprocessing units, and buyers. Customers are stakeholders that need an option to dispose of their waste. Actors involved in collection, storage, transportation, and classification are called collectors. These firms can be logistics service providers, waste management companies, municipalities, or retailers. Reprocessors dismantle products into materials and sell these to secondary buyers (ibid.).

In addition, organising the whole logistics network for product recovery can be performed by actors that are deeply involved in forward physical flows, either individually or jointly with other actors (de Brito and Dekker, 2003). Original Equipment Manufacturers, wholesalers, retailers, or stakeholders in the public sector may participate effectively as coordinators in these structures. Besides those that are involved in coordinating physical activities and combining resources, Flygansvaer (2006) and Jamshidi (2011) also introduced an additional type of actor, an organiser, which sets up and supports logistics structures for recycling. In Flygansvaer's study, this organiser was jointly formed by importers, manufacturers, and distributors of electronics products, who became members of a consortium due to legislative requirements, imposed by what Jahre et al. (2006) called the authorities.

As only part of the network is more explicitly driven by legislation, this thesis has a minor focus on public authorities as stakeholders, and the actors that are involved in product recovery processes are mainly defined according to the activities discussed in section 2.3.1. Following the view of de Brito and Dekker (2003), it is the actor roles determined by processes that are associated with reverse physical flows that are significant. Furthermore, an activity/role perspective is also present in a classification of actors used for the analysis of reverse distribution systems (Jahre et al., 2006; van der Wiel, 2012), where the analytical tools, related to the resource layer of the Industrial Network Approach have been applied. This terminology should therefore be an appropriate starting point from which to characterise actor roles in this study.

Therefore, very broadly speaking, actors in logistics networks associated with product recovery arrangements may be classified into two distinguishable groups. The actors who want, or are required, to[19] dispose of their objects at different stages of the product life are *disposers*. Disposers are the sources of inputs for product recovery processes in networks. They use their knowledge of object classification when they order collections. On the other side are actors who desire these items. These are known as *users*. Users can utilise objects in

[19] For instance, if the equipment is leased over a certain period of time.

combination with their skill and expertise for the production of new materials and products, or for consumption, in which case they are known as *end users*.

Collectors, *reprocessors*, and *distributors* are the actors that stand between and connect disposers and users of the products in question, or their parts and constituent raw materials. Collectors perform activities related to collection, storage, and transportation via their logistical capabilities, which are utilised in combination with warehouses, trucks, cages, and other load carriers. They amass and classify objects. An additional classification can be performed by reprocessors. Reprocessors are involved in product recovery options (such as repair, remanufacturing, or recycling), which are connected to the testing, classifying, dismantling, and reassembly of objects. Their specialised capabilities and equipment, such as testing tools and dismantling lines, enable them to arrange their internal activities and combine their resources. Distributors are concerned with buying, selling, classifying, and modifying objects (for example, adding new parts), while logistics service providers, who are part of forward supply and distribution networks, deal with inventory holding and transportation of products. For this purpose they can combine and recombine resources, such as different means of transportation, purchasing/sales competence, warehouse facilities, and information systems for buying and selling, and route/vehicle planning.

From an inter-organisational perspective, these actors organise product recovery structures in networks by combining resources and coordinating activities through business relationships. The importance of inter-organisational issues in logistics systems for product recovery has been recognised by, for example, Flygansvaer (2006), Huge-Brodin (2002), Zhang et al. (2014). Flygansvaer (2006) and Yang et al. (2013) showed that a change in the organising structure of business relationships enhanced performance in collection and recycling. Several authors (Guide and van Wassenhove, 2009; Srivastava, 2007; Toffel, 2004; Sharma et al., 2010; Sheriff et al., 2012; Choi et al. 2013; Govindan et al., 2014) have identified a need for more research on inter-organisational issues and business relationships within the product recovery context. Behavioural features of business relationships are some of the tools for theoretical description of the actor layer of networks within the Industrial Network Approach. In addition to behavioural features of relationships, in the next section other analytical tools connected to the actor layer of the ARA model are detailed in relation to product recovery settings.

2.5.2 Central features of actors

As interaction within inter-firm relationships is one of the essential concepts in the Industrial Network Approach, this section begins with a discussion about interaction in business relationships. This is followed by a description of the concept of actor positioning through interaction.

Interaction

The concept of interaction is one of the elementary pillars of the Industrial Network Approach. Håkansson et al. (2009, p. 33) conceptualised interaction as *'an important economic process through which all of the aspects of business, including physical, financial and human resources, take their form, are changed and are transformed.'* The greater the involvement of an actor in a particular interaction, the greater will be the effects on its activities, on its resources, and on the company itself. Some interaction processes are long lasting and some are temporary. In this way, interaction in business networks takes a wide variety of forms (Håkansson et al., 2009). Huge-Brodin (2002) concluded that frequent interactions or regularity in business relationships can enhance logistics performance in systems for waste collection and recycling. Apart from improving the performance, greater and permanent contacts and improved communication between the disposers and firms in product recovery can reduce uncertainty of supply with respect to the quality and quantity features of returned products (Garcia-Rodriguez et al., 2013).

Interaction processes include people from different organisational functions (Gadde et al., 2010). Interactions between firms in organising product recovery typically involve complex personal contacts. Contacts between people in organisations and firms, such as collectors, recyclers and distributors of used/reprocessed items, involve indirect connections and interactions with other companies in forward physical flows (de Brito and Dekker, 2003; Krikke et al., 2013). This highlights the appropriateness of a network view for the analysis of inter-firm structures in organising product recovery. The network concept takes into account interaction dynamics of the wider inter-organisational industrial web. This indicates that companies are not connected in straight lines composed of supply chains and/or marketing channels (Ford et al., 2003). This is valid in the case of both reverse supply chains and closed loop supply chains (Jena and Sarmah, 2014).

The greater complexity of networks induced by extended supply chains and product recovery includes supplementary relationships, or a lack of such relationships, with inherent interaction processes. Therefore, in several product lines, adaptations between reverse and forward physical flows are not conducted in an inter-organisational sense (Ferrer and Whybark, 2000; Flygansvaer, 2006; Garcia-Rodriguez et al., 2013). This is a result of undeveloped interaction and collaboration between Original Equipment Manufacturers and reprocessing firms on issues such as design for disassembly, which has led to a stream of research related to environmentally conscious manufacturing and product recovery that combines forward and reverse supply chains. However, this stream of research frequently uses a supply chain with a focal firm as the unit of analysis, rather than considering a network of supply chains (Ilgin and Gupta, 2010).

In contrast to this situation, interaction processes contribute to the creation of knowledge required for inter-organisational activity coordination and resource combining. Throughout the network, interaction and business relationships allow firms to develop adaptations and adjustments between resources and activities (Håkansson et al., 2009). These adaptations develop into inter-organisational interdependencies. Håkansson and Johanson (1987, p. 372) stated that: *'Through interaction, (firms) influence and adapt to each other's ways of performing activities.'* As interaction between organisations proceeds, the positioning of actors evolves.

Positioning of actors

An organisation can be described in terms of its business relationships and interaction patterns within the network. This position illustrates how an actor connects activities and resources that are under the control of other actors, both directly and indirectly. From a network perspective, an actor's position is also defined by how a firm is connected to the resources and activities of other firms. Hence, an actor's position needs to be regarded in light of how the actor coordinates activities and combines resources through business relationships on its supply and demand side (Gadde et al., 2010). In addition, a single business relationship may be composed of multiple simple relationships, including supplier to customer (and vice versa), competitor to competitor, and partner to partner (Ross and Robertson, 2007).

Actor positions in the network change when companies do business with each other and face issues, both on a daily basis and over a longer period of time (Håkansson et al., 2009). An example of this positioning involves electronics manufacturers in Japan (Toffel, 2004). Besides participating in the formulation of policies for coordinating a joint network for the collection and reprocessing of electronics waste, each manufacturer in Japan maintains one treatment plant in order to accumulate information about reprocessing costs and the effect that design has on these costs. Conversely, Flygansvaer (2006) stated that the lack of interaction and appropriate resource interfaces between manufacturers and recyclers create dismantling difficulties. Design, production, and use of new products are not adapted to the work of recycling firms (Winkler, 2011).

Flapper et al. (2005), Krikke et al. (2013), and Faccio et al. (2014) recognised the fact that firms sometimes share facilities and other resources for jointly coordinated forward and reverse physical flows when the activities involved in both of these flows display similarities. Toffel (2004) argued that manufacturers or their partners are more likely to perform product recovery when remanufacturing requires comparable, unique resources and experience to manufacturing or other activities associated with the physical flows of new products. Since collection is usually not the core business of an Original Equipment Manufacturer, a specialised logistics service provider usually performs this process more efficiently and to a lower cost, as it can exploit its specialised capabilities (Giovanni and Zaccour, 2014). This positioning is employed on a worldwide basis by Lexmark and Kodak (ibid.). Furthermore, in order to connect the logistics and marketing strategies, an intermediary involved in the distribution of used products can use the lowered reverse logistics cost to reduce the price of products and boost sales (ibid.).

These positioning and repositioning changes have effects on the whole web of actors in networks. Therefore, positioning and repositioning define the activities and resources in which an actor is involved, by relating them to other actors' positioning moves within the network. In this manner, positioning is a means of specialisation, which, in turn, is dependent on how other actors specialise (Gadde et al., 2010). Håkansson and Waluszewski (2002) studied the positioning behaviour of firms and mutual resource adaptations in the network for the collection and reprocessing of waste paper. Their study revealed that some of the actors that were far from being regarded as crucial to the collaborative development of a more environmentally friendly paper became central, thanks to interaction processes.

The nature of interaction in business relationships influences the positioning of actors in terms of activity adjustments and resource adaptations. Flygansvaer (2006) exemplified this by stating that customers of waste collection services (that is, disposers) usually display passive behaviour as suppliers of inputs in reverse distribution systems. She argued that deeper relationships with business disposers might create more organised product recovery arrangements. Huge-Brodin (2002) concluded that business relationships and the development of interaction between actors in logistics systems for recycling are not characterised by institutionalised maturity, which obstructs the organising efforts.

Power is another type of interactive social behaviour, and is related to the positioning of actors in terms of classifying inter-organisational relationships, objects, and functions. Gadde et al. (2010) provided a network perspective on power by focusing on the influencing force derived through an actor's network position via a classification of the firm's relationships. Huge-Brodin (2002) demonstrated that a network position in terms of size[20] and the company's relationship portfolio is one of the power bases in logistics systems for recycling. In addition, an intermediary has to be anchored at either the supply or demand side, since it is most vulnerable with regard to the attention given from suppliers and customers if it buys only a small part of a supplier's assortment and sells it on to actors for whom this assortment accounts for only a small part of their customer demand (Alderson, 1965). Therefore, an intermediary that is closest to the disposer (the primary end user) prefers to manage the collection as this intermediary ends up having more decision power and control over both the return rate and forward physical flows (Giovanni and Zaccour, 2014). Moreover, if this intermediary has the role of selling the reprocessed products to the secondary end user, and sets the prices on returned products, this will improve the performance and reduce the costs of reprocessing and reverse logistics (Choi et al., 2013). Since the retailer, who is the closest actor to the secondary end user, wants to keep the demand high by offering low prices, the

[20] For example, the total sales of each of the two actors in a relationship.

collector will try to collect as many products as possible. The economies of scale in collection will in turn lead to lower reverse logistics costs. Choi et al. argue that *'having the retailer as the supply chain leader can lead to the best result. This finding is very important as it provides a new scientific evidence to support the idea of changing the channel leadership from upstream manufacturer to downstream retailer in a CLSC*[21] *… the supply chain performance is worst when the most upstream member acts as the supply chain leader'* (ibid., p. 379).

The network position can be used for coercion and/or to exert direct and indirect influence over others through shared rules and values. Inter-organisational coordination of activities and resource combining through the application of classification systems, which contribute to defining the actors' positions in a network, are determined by the nature of inter-organisational relationships. Overly specific instructions in the form of rules stipulated by a more powerful actor may diminish opportunities for the contribution of knowledge by other, less powerful actors, who are supposed to perform the activities and combine the resources according to the instructions given (Hayek, 1982).

Insanic (2012) identified the existence of cooperative behaviour among competing firms who use classifications in order to develop cooperation with regard to different objects, customers, and activities. These domains of collaboration support the creation of materials and informational crossing and differentiation points for the sake of activity coordination and resource combining in transvections. Cooperative behaviour between competitors regulates the establishment of policies for the implementation of principles of postponement and speculation.

To summarise, in addition to cooperative adaptations (even among competitors) in business networks, there are also other types of social behaviour that involve conflicts between actors. These relationship features, and their relevance for organising product recovery, are discussed below.

2.5.3 The role of actors in organising product recovery in networks

According to the ARA model webs of actors, resource constellations and activity patterns are connected. In line with this model, actors organise activities and resources on firm, relationship, and network levels. On a relationship level, it is important for actors to develop activity links and resource ties in order to coordinate activities and combine resources involved in product recovery in an economically efficient manner. Interaction between actors, such as disposers, collectors, reprocessors, distributors, and end users, enables the organising of product recovery in networks by positioning and repositioning.

[21] Closed Loop Supply Chain.

Through a repertoire of different kinds of relationship behaviours, firms will position and reposition activities and resources in business networks. Hence, actors have multidimensional identities, as their positions and positioning are dependent on the inter-organisational relationships in networks involving reverse and/or forward physical flows. This section deals with the nature of business relationships and the role of information exchange in activity coordination and resource combining in networks.

The nature of business relationships

Business relationships contain mixtures of confrontational and collaborative interactions (Ross and Robertson, 2007; Håkansson et al., 2009). Certain interactions are linked to individual purchases, while others relate to the continuous movement of large volumes of physical goods (Håkansson et al., 2009). A supplier might be able to contribute a specific solution for a particular customer at a particular time; even some ad hoc and short-term projects can involve intense interaction that might leave significant imprints on the companies involved. Thus, the involvement of actors in relationships has an impact on the outcome of actor positioning and the interaction processes within business relationships.

In order to conceptualise interaction, Gadde et al. (2010) divided inter-organisational relationships into two diametrically opposite approaches, *high-involvement* and *low-involvement* relationships (although both approaches are often blended). A *high-involvement business relationship* is associated with large adaptations in the resource and activity dimensions (ibid.). This type of relationship can generate large cost and revenue benefits over a longer period of time because it can provide customised offerings and relationship specific solutions. Other benefits in high-involvement relationships are related to flexibility, improved service levels and efficient and smooth physical flows, such as in ‘just in time’ and ‘build to order’ production. However, there are substantial costs involved in the related coordination, adaptation and interaction, which increase relationship handling costs. High-involvement relationships take time to develop because the supplier/seller and buyer/customer need to know a lot about each other before establishing a high-involvement relationship. It becomes possible for partners to improve their skills and capabilities through interaction. *Low-involvement business relationships* are handled with limited resource adaptations, activity interdependencies and interaction. Since products and services are usually standardised, this approach leads to minimum resource and activity adjustments and adaptations. Complementarity among activities in transvections is normally not close in low-involvement relationships. Shipment and order-processing activities are more standardised compared to high-involvement relationships. This implies low relationship-handling costs. Low-involvement relationships are frequently connected to the opportunity to play off many business partners, while high-involvement relationships are related to a much smaller number of counterparts.

Gadde et al. (2010) proposed that close collaboration occurs via the systematic adjustment of operations between actors during periods of uncertain supply and demand, such as those characterised by periods of economic recessions and business peaks. Joint considerations of volumes, lead times, frequencies, and inventory levels by means of classification systems, for example enterprise and materials-planning systems, will improve continuity, as more accurate data will generate more reliable forecasts. This kind of coordination and integration also plays a critical role in product recovery operations (Rahman and Subramanian, 2012). Inter-organisational collaboration reduces the need for safety stocks at each and every actor, as well as associated costs, such as those related to the risks of obsolescence.

As argued by Alderson (1965), cooperation is as prevalent as competition in business. This is also true for inter-organisational relationships. Thus, inter-organisational relationships can be characterised by both collaborative and confrontational features (Gadde et al., 2010). In order to describe context dependent but frequent cooperation and competition in marketing channels, Gettell (1950, p. 93) coined the term *pluralistic competition,* which he defined as *'the simultaneous cooperation and conflict between and among individuals and business units that characterize the market place'.*

An example of simultaneous competition and cooperation in the product recovery setting was provided by Guide and van Wassenhove (2009), who argued that there are risks of having refurbished equipment compete with the sales of new products supplied by Original Equipment Manufacturers. A manufacturer can choose to recycle or remanufacture in order to prevent intermediaries from reselling the manufacturer's products at a lower price in the second-hand market (de Brito and Dekker, 2003, Lebreton, 2006). According to Srivastava (2008), the Original Equipment Manufacturer may then increase cooperation throughout the supply and distribution network in order to obtain the product after its primary usage and give the product multiple lives, as the suppliers start to manufacture more standardised parts and modules across several generations and families of products. Some authors, i.e. Xiong et al. (2013), even claimed that both the Original Equipment Manufacturer and its supplier end up in a lose–lose situation when the manufacturer chooses to remanufacture on its own and thus compete with other refurbishers.

Competitors can cooperate by joint participation in research projects, the determination of production standards, the enforcement of fair-practice codes, and, sometimes, the support of wholesale and retail distributors by extending credit and lending money (Gettell, 1950). An example of collaboration between competitors involved in organising product recovery set-ups is taking place in Sweden (Huge-Brodin, 2002) and Japan (Toffel, 2004). Competing electronics manufacturers have formed consortia for the collection and reprocessing of their end-of-life products. Toyasaki et al. (2012) and Garcia-Rodriguez et al. (2013) demonstrated that collaboration between companies via joint investments in information systems generates a win–win situation and leads to lower overall costs. In order to regulate competition between new and returned products, Chen and Chang (2012) advocated revenue sharing between an Original Equipment Manufacturer and a remanufacturing partner as a coordination mechanism in case of a high remanufacturing cost to the manufacturer, large market size of the new product, and a high degree of substitutability between new and remanufactured goods. Papachristos (2014) advised actors who provide competing new and remanufactured products to establish joint reverse logistics networks in order to improve the environmental performance of the whole system. Horizontal and vertical coordination in the product recovery network is also necessary to obtain a profitable return rate and a fast and responsive reverse supply chain (Krikke et al., 2013)

Flygansvaer (2006) and Faccio et al. (2014) showed that the establishment of close relationships with organisational disposers enables increased supply of volumes of homogeneous goods, which can make capacity utilisation in collection and dismantling less challenging than in handling used items from consumer disposers, in which product flows consist of small, high-frequency, heterogeneous volumes. They indicated that the integration of effective information flows in reverse distribution systems is crucial in coordinating effective physical flows. With regard to disposers, Garcia-Rodriguez et al. (2013), Flygansvaer (2006), and White et al. (2003) described that many disposing organisations supply inputs on a case-by-case basis, which creates organising challenges in terms of intermittent flows.

The lack of inter-organisational coordination and integration of reverse physical flows is often caused by information paucity and asymmetry that create confusion and inefficiency (White et al., 2003). For example, reprocessing businesses often deal with facilities staff, who have little data about the composition of, or modifications to, IT equipment that occur during the utilisation (or repair) of the product (ibid.). Furthermore, equipment that needs to be dismantled may be transported unnecessarily to an inspection facility, because there is a lack of information about the state of the product (Blackburn et al., 2004; Zhou and Piramuthu, 2013). In most cases the disposer has to pay for logistics services. On the other hand, greater information availability, through consortia, regulations, or long-term contracts, can improve the management of disassembly and reprocessing, and therefore lower the costs of reverse logistics services (White et al., 2003; Lee and Lam, 2012).

Nevertheless, actors in inter-organisational structures can choose not to share information for several reasons. One reason for information withholding in business is that information is considered a source of power (Mason-Jones et al., 1997). The fear of losing power to another actor is used to explain information distortion and the reluctance to share information in inter-organisational settings. This opportunistic behaviour with regard to the withholding and/or distortion of information is nevertheless often coupled with increased transaction costs (Stern and Reve, 1980). Indeed, both Stigler (1961) and Akerlof (1974) claimed that trust and reputation economise on transaction costs. Huge-Brodin (2002) showed that superior information access can be used by a firm to establish itself as a central actor in controlling reverse physical flows. However, this situation is largely influenced by the firm's network position, and less so by a desire to withhold information from other actors or to behave opportunistically (ibid.).

Business relationships that involve leasing entail secure agreements regarding timing, volume and quality of product recovery (that is, reduce the uncertainty or lack of information about time, form, place, and identity). Indeed, Thierry et al. (1995) argued that '*Lease companies usually have more information on the quality and return of used products.*' This is attributed to high-involvement approaches in business relationships in which companies have close interaction and high levels of information sharing regarding maintenance, repair and operations. Permanent communication and information exchange between primary end users (disposers) and product recovery firms reduce uncertainty and improve the performance of reverse logistics (Garcia-Rodriguez et al., 2013; Krikke et al., 2013). The role and structure of information exchange between organisations is discussed in the following section.

The role of information exchange

The flow of goods is intertwined with information exchange. Information exchange between actors in business relationships improves organising in terms of resource combining and activity coordination. Indeed, information exchange is a precondition for activity coordination and resource combining in business relationships. Classification systems are applied in order to organise work and division of labour in a hierarchical and pragmatic manner (Bowker and Star, 1999). From an inter-organisational viewpoint, contemporary information systems are designed to track and trace the position of single items in logistics flows in a much more detailed way, which enables more efficient matching of supply and demand (Gadde et al., 2010). In the selection of alternative product recovery options, the instantaneous tracking of an object's and its components' position and other features can be achieved by means of an RFID system (Zhou and Piramuthu, 2013; Kim and Glock, 2014; Kumar and Rahman, 2014).

Information content that is registered and identified in firms' information systems concerns the changing product characteristics and states. This information involves data about the different forms, times, places, and identity features of goods. Classification systems are necessary for activity coordination and resource combining in time and space. Information systems can alter previously registered data in order to adapt this type of classified information to the needs of various actors (Engelseth, 2007). As described above, positioning is a process through which actors in business relationships specialise in the resource and activity layers of business networks. Therefore, the use of information among actors may vary, as different resource features need to be combined with the features of objects through interfaces and classification principles. In a similar vein, information that is needed for efficient and effective coordination of activities is actor dependent.

Alderson (1965) explained that grading and standardisation (reduction of information complexity by partial homogenisation, in Alderson's terms) makes transactions more efficient. It is the routine types of information that become central in economising on time and effort in searching or informational sorting. In order for these conditions to prevail, the supplier's identification of the object must match the buyer's need specifications (ibid.).

Information mismatch is one of the problems identified in organising product recovery that is caused by the lack or abundance of information (that is, uncertainty and complexity). Thus, proper information handling among organisations is central to these milieus, as uncertainties with respect to the features of product returns are greater (Ketzenberg et al., 2006; Asif, 2011; Tuzkaya et al. 2011). The importance of characteristics to individual actors is also changed and modified during the phases of a product's development, production, distribution, use, and product recovery. The list of product attributes used by the product development is not the same as that on the sales brochure, even if the two lists of characteristics are related (Alderson, 1965). These properties are also different from the standpoint of a sub-contractor who designs and manufactures parts, although the attributes of products need to be interconnected in an organised manner.

Object features and types that are attached to certain values are applied in order to group the objects that share a number of characteristics by, for example, recyclers. As explained above, transformations may be combined in different ways with respect to place, time, form, and identity in order to exploit economies of scale. However, time can have a negative impact on appropriate object transformations of products such as electronics. These have short innovation cycles, and might be sent for materials recovery even though they are fully functional, simply because some of their characteristics are outdated. These valorised characteristics of used products and object types are applied in order to assign them to facilities for the adequate product recovery option.

Following the conclusions of Shannon and Weaver (1949) that information provides value by reducing uncertainty, Ketzenberg et al. (2006) argued that efficient coordination of processes in product recovery environments requires accurate information on the timing and quality of product returns. This coordination can be achieved through a joint investment by actors in business relationships in information systems that track the location and condition of products, and/or through the availability of timely and correct information, which could accommodate balancing returns with demands by the partnering firms (Kokkinaki et al., 2004; Asif, 2011; Toyasaki et al., 2012; Garcia-Rodriguez, 2013). The connections between information sharing and the nature of inter-organisational relationships are summed up in the following section, which considers research issues associated with the actor layer of the Industrial Network Approach.

2.5.4 Research issues

Business relationships may simultaneously exhibit several types of actor behaviours, including cooperation and conflict. These features have an impact on the performance of inter-firm organising efforts in activity patterns and resource constellations. The level of involvement in business relationships affects inter-organisational coordination of activities and resource combining of product recovery arrangements between actors. Some business relationships involved in product recovery settings of networks are not characterised by developed inter-organisational coordination.

Resource constellations with corresponding combinations, and activity patterns with related interdependencies, influence the organising structure of business relationships in product recovery arrangements. This refers to interactions of actors involved in reverse flows of various product recovery options, and between forward and reverse physical flows.

Network positions, features of business relationships, and the level of involvement in business relationships have an impact on information exchange between actors, which is vital in linking activities and resource combinations between firms. Resource adaptations enhance the performance of resource combinations in product recovery through interfaces developed between interacting objects, organisational units, organisational relationships, and facilities. Interactions between resource constellations for forward and reverse physical flows, and for different product recovery options, may display a variety of tensions, which actors have to manage.

Actors organise activities and resources. Therefore, important dimensions of the organising of the actor layer in product recovery are derived from the previous discussions concerning activities and resources. The first task in the exploration of the actor layer is to identify what actors are involved in the transvection activities, and what role they play in the combining of resources. The specific research issues in the actor layer concern:

- The identification of actors who coordinate activities and combine resources.
- The analysis of how interaction and relationship involvement are used in activity coordination and resource combining.
- The analysis of how different kinds of information exchange affect activity coordination and resource combining.

In summary, these research issues are formulated in order to gain an understanding of the nature of business relationships, and how these affect activity coordination and resource combining in product recovery structures. Activity coordination and resource combining take place within a framework of rules that are parts of classification systems; this will be discussed in the subsequent section.

2.6 Organising product recovery using classification systems

Sorting and transformation are two elementary activities in transvections, which are distributed across resource constellations and organised by firms in actor webs. This classification of goods is at the heart of the economic organisation because the qualities, and the establishment of the list of qualities, of an object involve the linking up or, rather, the co-construction of supply and demand (Chamberlin, 1946). Sorting implies a decision with regard to the next transformation, which means that it has to be based on some type of logic. This logic includes certain principles that classify objects. This means that objects have to be classified in order to be assigned to transformations and sortings performed by actors who combine resources in transvections. The next part of this chapter deals with the basics of classification and rules (section 2.6.1), the elements of the classification systems (section 2.6.2), and the role of classification in the transformation of objects (section 2.6.3). In addition to defining a class and classification, the section below (section 2.6.1) contains two subsections that outline different types of rules in organising product recovery, as well as the related standards, and instructions.

2.6.1 Classifications in product recovery

Structuring of information by means of classification of objects, people, and/or activities into categories is a common feature of a modern developed society (Bowker and Star, 1999). In fact, it is not possible to perform any quantitative mathematical or statistical analysis on supply and demand of used products if there is no agreement between the actors on the features of objects that should be recycled or remanufactured. In order to provide a practical or theoretical description of objects in time, place, identity, quantity, and form dimensions, uniformities and differences between them have to be established. Objects can, for example be classified by their origin and descent (genetic order), date received (temporal order), or frequency of use (functional order) (Bowker and Star, 1999).

Uniformities and differences between objects are conceptualised by the classes that arise over time from durable interaction among communities of practice, and are used for cooperation across social worlds (ibid.). Bowker and Star (1999) state that classes are metaphorical or literal boxes (classifications) into which things can be put in order to do some kind of work; these classes involve *"a spatial, temporal, or spatio-temporal segmentaion of the world"* (p. 10).

In the present case, an object that is about to be sorted has certain features. Its belonging to a certain class has to be determined, and this decision is aided by certain criteria. In order to direct the object into adequate transformations, there has to be a number of values and criteria that can be attached to each class. For example, Mahmoudzadeh et al. (2013) found that scrapyards specialise in a limited number of product classes as their input.

The classes may or may not be mutually exclusive, and subject to actor-specific workarounds involved in the practical use of both ad hoc and standardised classifications. A standardised classification approach imposes a system even for the actor-specific organisation of actions and things. Furthermore, local adaptations entail the use of classes that are not standards, although the classes themselves may be a part of a standardised classification system.

Classification is decisive at the crossing and differentiation points, and influences which sorting and transformation activities are undertaken in transvections. Organising between those who supply and those who demand a used or recycled object, and those who use it, includes matching of the object qualities between actors, and activation of interfaces between numerous resources. In order to transmit information about the most relevant features of an object, a classification system and resource interfaces in terms of classes of objects and activities have to be developed and established (Bowker and Star, 1999). Classification systems constitute an information-collection and -processing infrastructure wherein the aim is to enable effective organising of product recovery. Various separate organisations are able to apply classification systems in order to process, retrieve, and put to use dispersed information and knowledge in order to combine resources, and execute and coordinate sortings and transformations in crossing and differentiation points. In this manner, firms in product-recovery networks can use their skills and knowledge of their particular settings for diverse ends.

Structured daily interactions between organisations are facilitated through rules, as the actors that perform activities on objects must use classifications in order to assign the used objects to resources for transformation. Actors supply and demand objects by means of classifying and transforming them through familiar values and characteristics. The quantity and quality of information is regulated by stabilised classes at the boundaries between actors in product recovery settings. At these boundaries, the object classes have to be fixed to a higher degree in order to take the assigned information, transform it, and classify it according to another set of classes adapted for the use of that information in a separate and specific context. A customer order has to contain a firm description of what is bought, at what price, in what quantity, and when, how, and where it has to be delivered. By doing this, the actor who receives the information will be able to apply it in his or her own domain of action.

If a decision at either an information or materials differentiation point is made to recover raw materials in an object, it may change the materials' identification according to the sorting rules for recycling. In other words, the applied classifications and the related rules produce complementarity towards actors that specialise in alternative product recovery options. Moreover, given a sufficient period of time between the information differentiation point (that is, when the information exchange on the delivery of an object is finalised) and the materials differentiation point (when the object is physically transferred to an actor), organisations will be able to create means for effective adaptation of rules in the transvections. This enables simultaneous management and a partial resolution of conflict between diversity and uniformity.

Besides being designed and developed by the actors, the classification system constructs the differentiation points and the community for which that system will serve as the information infrastructure (Bowker and Star, 1999). Classification systems are organised by the work practices that are already in place, before these practices are classified and documented. Via their sorting rules, classification systems aid in coordinating activities and combining resources in product recovery.

Different types of rules in organising product recovery

Whether explicit or implicit, written or unarticulated, rules dominate every social behaviour and organisation, from games through culture, and religion, to economics and business (Ostrom, 2005). Alchian (1950) and Gode and Sunder (1997) even claimed that the institutional structure of rules has a greater impact on the efficiency of transactions than individual choice and cost–benefit calculations. Rules and instructions of some kind are also involved in various approaches to management (Alderson and Green, 1964). This is also applicable to product recovery arrangements, since they also involve interactions and transactions between numerous actors.

The means by which this integration, coordination, and cooperation of actors in networks of inter-organisational relationships is achieved and performed is not evident in product recovery research, despite the fact that rules, as interfaces that organise interaction between humans, are highly significant for the understanding of society, social institutions, markets, and organisations (Hayek, 1982, 1988; North, 1990; Williamson, 2000; Brunsson and Jacobsson, 2000; Hodgson, 2004; Ostrom, 2005). More explicitly, Brunsson and Jacobsson (2000) claimed that standards (as rules) have been insufficiently theoretically investigated in general – and this is valid for organising product recovery in particular. Callon et al. (2002) demanded more research on qualification rules in economic organisation on behalf of firms, social scientists, and political decision-makers. One of the ways in which to analyse management of product recovery networks in this study is by applying the current knowledge and frameworks about classification systems and their impact on inter-firm organising since the importance of rules in interactions between actors has been acknowledged by many researchers and scholars, but not extensively on the level of inter-organisational relationships.

Most of the general theoretical approaches regarding rules, interfaces, and classifications either focus on classification/sorting systems (e.g., Star and Griesmer, 1989; Bowker and Star, 1999; Star, 2010) or classifying rules themselves (e.g., Hayek, 1982; Williamson 2000; Ostrom, 2005). North (1990) emphasised institutions, which he defined as the underlying rules of the game, and focused on how single organisations alter rules. Brunsson and Jacobsson (2000) attempted to find compatibility between different types of rules and various kinds of economic organisations, and classified rules into norms, standards, and directives with regard to the types of organisations in which these classified rules are most frequently and widely used. Inspired by Williamson's (1975) market-hierarchy dichotomy, the authors stated that:

- Norms are descriptive of normative communities (such as a profession, village, nation, etc.).
- Standards, such as Environmental and Quality Management Systems (ISO 9 000 and 14 000 series), are representative of markets and industries.
- Directives are characteristic of hierarchies; that is, formal organisations.

However, Brunsson and Jacobsson (2000) did not take into consideration the fact that industries consist of business relationships and are interconnected through inter-organisational relationships. This also applies to Hayek's (1988) treatise of what can be perceived as the network governance of the *extended order* governed by means of abstract rules (those that are followed by an undetermined number of people, regardless of the particular setting). This is comparable to the use of Incoterms rules[22], which are widely used by actors in a great number of markets and industries. In particular, in the research on inter-organisational relationships, there is no theoretical framework to capture the interaction between classifications and various types of rules. In addition, the role of rules in inter-organisational coordination and interfaces in product recovery has not been extensively considered.

Gadde et al. (2010) classified collaboration vis-à-vis, among other things, interfaces into three supply network strategies, from standardisation of transactions and interfaces; via a mixture of standardised interfaces and high-involvement relationship with extensive interaction; to close and intense interaction between buyers and sellers in search of effectiveness and efficiency. Insanic (2012) only briefly mentioned the connection between the level of development of the interfaces and the nature of relationships in managing a product recovery network. There is therefore room for research on inter-organisational collaboration from a relational and network perspective on interfaces, rules and classifications used for coordination and information exchange that support physical flows. This is because classification of products determines who performs product recovery and what product recovery option or reprocessing alternative becomes chosen.

One of the ways of managing an organisation, a marketing system,[23] or a supply chain is via rules and instructions (Alderson and Green, 1964). Alderson and Green (1964) state that

[22] International Commercial Terms are a series of pre-defined commercial terms published by the International Chamber of Commerce (ICC) that are widely used in international commercial transactions or procurement processes.

[23] Within which a transvection is a single unit of action (Alderson, 1965).

management by decision rules[24] involves the explicit tuning-up of rules of thumb and determination of the values of physical, monetary, and informational flow rates in production–distribution–use systems, such as those developed by Forrester (1958, 1960).[25] This thesis focuses on inter-organisational rules and instructions for activity coordination and resource combining of transvections within already established business relationships.

Rules, standards, and instructions

Abstract rules, stored in case independent standards, are the content of expert knowledge (Brunsson and Jacobsson, 2000). The abstract knowledge that is de-contextualised in space and time is transformed into standardised abstract rules. A dynamic interaction exists between standardised abstract rules and direct instructions, as these phenomena vary in their imperative force and level of internalisation, and how voluntary they are (ibid.). Deregulation can often mean that some direct instructions become standardised, abstract rules. On the other hand, regulation can imply legalisation of rules, of which many already are in use (ibid.).

One type of regulation that is enforced, rescinded, and reinstated on the same hierarchical level, although not necessarily originally created by an authority, is abstract rules, which can be designed by the actors who are closely involved in managing a resource or performing actions (ibid.). These abstract rules are applied to situations wherein many facts and circumstances were not predicted by the designers of the rules (Ostrom, 2005). Abstract rules govern a web of actors by providing general guidance to activity coordination and resource combining in transvections in light of high uncertainty, where the particular and diverse facts and objectives are only known to individual and separate actors. The particular parts of the web of actors rest upon specific events known only to those who obey the rules and apply them to the facts, consisting of adaptations to a set of particular data, which will not be known in their totality to anyone (Hayek, 1982). The primary analytical focus of this study is on obtaining an understanding of how established classification systems with their corresponding rules, including those on the national and international level, interact with the coordination of sorts and transformations of objects between organisations.

As noted above, abstract rules are applied to situations in which several specifics, outcomes, and circumstances were not predicted by the rules' designers (Shivakoti and Ostrom, 2002). With regard to the extent of direct control, there is a difference between direct instructions and abstract rules. Direct instructions represent a way to solve a problem (Black, 1960), and refer to a procedure related to how to perform and coordinate activities and combine resources, which are adopted by the actors as strategies and plans within ongoing situations. These plans normally characterise organisations such as firms and governments, and provide means for

[24] By both rules and instructions.

[25] The theoretical framework of Forrester (1958) is still very influential in the literature on Supply Chain Management.

actors to fulfil particular results aimed at by those who are in command (Hayek, 1982). The authority of an organisation decides the role of each member of an organisation, whose position is assigned in light of particular purposes and ends assigned to the individual by the management (ibid.).

On the other hand, according to Hayek (1982) there is an interaction and compatibility between direct instructions and abstract rules, since abstract rules alone cannot organise each actor's activity structure or resource collection. Direct instructions are subsidiary to abstract rules. More precisely, direct instructions are a complement to specific, and abstract rules. Another difference between abstract rules and direct instructions is that the latter are more frequently backed by sanctions. Knowledge of these rules is advantageous because they represent the gains from specialisation that arise *"when people can use other people's knowledge to their own advantage without themselves acquiring it"* (Vaughn, 1999, p. 133).

Standardised rules are abstract rules that characterise a general configuration with respect to the specific implementation of standards (for example, some of the series of standards issued by the International Organisation for Standardisation, such as ISO 9000 or ISO 14000, according to which many firms involved in product recovery configurations operate). Brunsson and Jacobsson (2000, p. 40) provided their own definition of standards as *"abstract, written rules which apply to many cases; the facts of each case are considered less important."* Abstract rules (such as those of the International Organisation for Standardisation or the International Classification of Diseases) refer to a complex structure in which interdependent actions are determined by information and guided by the purposes of separate actors (Hayek, 1982). For example, the International Classification of Diseases, which includes rules for interpretation, change, and presentation, serve the often conflicting needs of multiple local, national, and international information systems of physicians, medical insurance companies, epidemiologists and other researchers, and government health officials (Bowker and Star, 1999).

Brunsson and Jacobsson (2000) argued that standards create diversity, despite their purpose of generating uniformity. Uniformity implies that many processes, objects, or the form of organisation are identical. However, even though standardisation is usually perceived as a means by which to achieve similarities among things and actions, it is also utilised in order to distinguish between objects, actors, and activities. Following a standard – that is, an abstract rule – entails delivering similar objects on similar occasions. From the viewpoint of their general application across many actors, settings, and national borders, standards produce uniformity over space and time. In the case of standards that are diffused in an industry, a great number of actors will display a similar behaviour or activity structure in a great number of instances. Following abstract standardised rules means that an abstract rule is adapted to a situation specific context.

Since standardised rules are devised to regulate uniformity, they make existing diversity more visible. According to Brunsson and Jacobsson (2000) there is an interaction between uniformity and diversity; the authors state that the uniformity created by rules and standards generate free zones for diversity to be discovered, and utilised, by both business partners and competitors. Therefore, uniformity and diversity are highly interdependent. Sorting rules and classifications are an aid in creating uniformities for the sake of economies of scale, and in order to generate differentiation according to the counterpart adaptations on the supply and demand side of an actor.

Firms, regulators and standard-based organisations, such as trade associations, organise interaction in the networks of which they are a part, or for which they create rules. These organisations invoke rules for the sake of regulating the degree of uniformity and diversity among actors and the resources they combine and employ, and activities that they perform and coordinate. From the behavioural viewpoint, standards-based organisations may create boundaries via classification systems where competition is not allowed, while at the same time generating an arena or a space of rules, and object classes or product characteristics, where proliferation may take place and be advanced. For example, if all components of PCs were to be be standardised in terms of their technical properties, or the functions that they perform, there would be less room for diversity in the technical aspects or form dimension. Nevertheless, the standard would also demarcate properties that are accessible for variety, such as price, design, delivery terms (that is, rules), and other product utilities (ibid.).

The rules and the classification system as a whole are altered over time for the sake of incorporating changes in selection and assignment to resources of transvections. For instance, in the PC industry, metrics or reference values related to the processor speed, the amount of memory, and the size of the screen or laptop have been changing according to the course of technological development. This information has to be transmitted through the reference values of objects to the actors who are dealing with used objects, so that they can make correct decisions regarding the selection and assignment of objects to resources such as facilities for recycling or transportation. In this way, the information is not simply gathered into a generally accessible bundle by a classification system.

Differences and uniformities between objects and their classifications become stabilised as the actors become accustomed to certain classes. Learned classes represent sunk costs and facilitate the mobilisation of a familiar and similar type of information (Callon et al., 2002). With regard to classification systems, it becomes essential to balance the costs of data storage, collection, and processing against the need for a well-ordered and, in a sense, parsimonious repository that can be used to support routine work (Bowker and Star, 1999). The work conducted by each organisation is determined by interaction via classification systems. Therefore, in this thesis classification systems are considered as both interfaces and facilities. This is motivated by the fact that classifications contain information about how to combine products, organisational units, organisational relationships, facilities and information about these entities, and rules on how to classify and transform the resource entities with regard to certain values. Sorting is based on classification systems that incorporate restrictions, privileges, and limits with regard to certain results and outcomes in the form of classes, reference values and rules.

2.6.2 Central features of classification systems

People involved in organisational relationships and organisational units classify other people, organisational units, items, goods, products, services, functions, processes, events, and social relationships according to various rules. The rules of numerous social settings have been frequently subject to theoretical classification by institutionalists and researchers in the field of organisation theory. As stated above, a number of scholars have also analysed classification systems (e.g., Star and Griesmer, 1989; Bowker and Star, 1999) and classification of rules (e.g., Brunsson and Jacobsson, 2000; Williamson, 2000; Ostrom, 2005), but not their relation, from either a network or an inter-organisational perspective. This section discusses the elements of classification systems: classes, reference values, and sorting and transformation rules.

Classes and reference values

In this thesis, the classification systems consist of the *object classes* that define object features which can be valorised quantitatively and/or qualitatively by means of reference values with regard to input and output of an operation or a resource such as a facility – that is, *reference input and output values*, which are applied intra- or inter-organisationally. These reference values can describe minimum or maximum levels, or recommendations on such levels. Hence, apart from changes in form, time, and place that are associated with the creation of economic utilities, the business network facilitates transformations in price, quantity, and identity. *Transformation rules* are applied in the bridging and matching of certain input and output qualitative and quantitative values (reference qualities and quantities) determined by sorting. These reference input and output values, which reflect limits, can become too rigid and routinised, which is a situation that requires the discovery, addition, subtraction, interpretation, and reinterpretation of categories in interactions with other actors.

In addition to these intangible properties, all classification systems on a small or large standardised scale are material, as well as symbolic: *"All classification and standardisation schemes contain blends of physical resources, such as paper forms, plugs, or software instructions encoded in silicon, and conventional arrangements such as speed and rhythm, dimension, and how specifications are implanted"* (Bowker and Star, 1999, p. 39). Examples of well-known, general-purpose classification, measurement, and rule systems include calendars, addressing systems, postal codes, Incoterm rules for supply, delivery and transportation, the Periodic Table of Elements, the International Classification of Diseases, and the International System of Units.[26]

These general assets are applied internationally, and among thousands of actors (ibid.). For example, the information distributed through the International Classification of Diseases is used to create electronic medical records and assess equipment and personnel needs, as well as to derive vital statistics, which all have a major influence on the costs and policies of a large number of organisations.

Especially in large-scale, interlinked networked information systems, the interdependence by which classes and social worlds are fitted to each other and come together results in a convergence between the information artefact itself and community that utilises it (where this artefact might include a classification system, a database, an interface, etc.). In other words, the actors support the information artefacts, which in turn constitute the social worlds that the actors inhabit. The choice of structure mirrors how one sees objects; conversely, the importation of the world through the projection of social classes confirms the reality (Latour, 1993).

The definition of the degree of ambiguity that is appropriate to delineate the product in question is a central issue of every classification system (Bowker and Star, 1999). Recording as much information as possible is very expensive with regard to administration costs. Hence, if every possible relevant piece of information were to be stored in the classification schema, the system would become entirely unwieldy as difficulties would arise in the search and retrieval (that is, sorting and transformation) of information (ibid.). The level of ambiguity, as well as the number and types of classes, may vary across organisational units who combine resources in business networks. The classes of a classification system make the cost of data collection outside of the framework higher, because the infrastructure enforces a certain understanding of a context. The actors have to decide on boundaries or product classes that will be valuable for the future. Sorting rules are thus essential to ordering human interaction across boundaries (ibid.).

When it comes to classification systems in any type of environment involving organised activities, conflicts, concessions, and compromises of interaction give rise to the classes of information about objects, people, and information within the classification system. Standardised classes representing the features of a used object are a special type of category, developed to classify the world in generic terms. Conversely, ad hoc classes of information about, for example, recycled objects may not become standardised if they are limited to an individual or a local community, and/or are of limited duration. Another distinction between

[26] This is the most widely used system of measurement in science and commerce. The units of measurements within the system are based on seven base units.

local or intra-firm classes and national/international standardised classes concerns the fact that standards are often enforced by legal bodies mandated by organisations such as manufacturers' associations or governments. One of the traits that are archetypical for standardised classifications and rules concerns the fact that a standard spans more than one community of practice (or site of activity). The standardised classes are used for multiple purposes by a wide range of groups, which makes them inert and expensive to change (ibid.). A characteristic of an object expressed in the units of the International System of Units can be used to describe myriad objects, which is how the ubiquity of interrelated standards and classifications form an integrated web of interoperability and integration.

Classification principles and sorting rules

Classification systems facilitate the coordination of work among various actors. The distributed knowledge and information that is contained in the classification systems can be applied in numerous ways, and for different purposes. Hence, designers of global classification systems must cope with uncertainties relating to quality and quantity, and apply standards using a rule of thumb, which involves the creation of residual classes (Bowker and Star, 1999). For example, the International Classification of Diseases even contains a set of rules for using this classification system, including instructions on what to do in ambiguous situations. In the product recovery context, sorting rules are used to handle the uncertainty of supply, since the properties of objects that have been disposed of require the implementation and application of certified standardisation tests and codified measurements.

Apart from generating uniformity and diversity among objects, the object classes are used to identify, collect, store, retrieve, and transfer characteristics of used objects between actors in the network, or, more simply, to sort and transform information. The characteristics of objects can be nested in the object classes of standardised classification systems such as the International System of Units. Sorting rules are applied in order to direct objects between transformations. During each sorting, these objects have to be classified in one way or another. This classification can be based on different principles.

Taylor (1995) argued that there are two elementary kinds of classifications with regard to the possibility of development and alteration of classes between the actors: *Aristotelian and prototype classifications* (Rosch and Lloyd, 1978). Aristotelian classifications work according to a set of binary classes, which are utilised to describe a new or used object. Each level of classification entails a choice to demarcate belonging of a member of a population into one, and only one, class. For example, *"in the universe of polygons, the class of triangles consists of figures that have three sides"* (ibid., p. 62).

However, in reality, the classifications used in society are much fuzzier, according to Rosch's *prototype theory* (1978). Prototype theory suggests that people have a broad and subjective picture in mind of what an object is. The definition of a new or recyclable object is blurry and supported by analogies and metaphors in *prototype classification*. Hence, actors call up a best example from their past experience and then see whether there is a rational or metaphorical relation that takes us from the example to the object under investigation. For instance, different groups might come up with different examples of what a piece of used furniture is. For some people this would be a chair or sofa, while for others it would be a bed or table (Bowker and Star, 1999). In prototype classification, heterogeneous objects are linked via the sharing of key features (ibid.). In agreement with this analysis, Hayek (1952) claimed that people never perceive unique properties of individual objects, but only properties that the objects have in common with other objects, in order to place something into one of several object classes. Analogically with regard to dissimilarities between items, prototype theory proposes that there are levels at which people most easily and naturally distinguish between objects. Therefore, classifications are applied in order to create similarity and diversity.

To conclude the discussion on these two elementary types of classifications, Bowker and Star (1999) claim that at a certain points in time an object can be classified unanimously by means of Aristotelian classification. However, no classification system in practice displays Aristotelian properties because *"the world is always slightly out of reach"* (ibid., p. 105) and cannot be contained in the classification system. Therefore, prototypical and Aristotelian types of classification are often used simultaneously.

Classes can be connected to *loosely or tightly coupled categories* with regard to their longevity (ibid.). Tightly coupled categories and properties are more stable, while the loosely coupled characteristics can be easier to alter (ibid.). Bowker and Star (ibid.) explain the difference between the tightly and loosely coupled categories using a description of a person's attributes in relation to their durability, where their sex is much more persistent than their position in a queue at a supermarket. With regard to product recovery, the tightly coupled categories are related to the raw materials, while the loosely coupled categories are associated with features such as the amount of memory and the processor speed of a PC. This is because raw materials can be used in a wider range of products than PCs, which have a rather short sales life cycle.

With regard to the quality and relevance of information to various actors, classifications can be *topological* or *typological* (Lemke, 1995). The development of foreclosed *typologies* or classes in order to collect, store, transfer and retrieve information is a way to create a predetermined and fixed number of classes. It may be thought of as a way to diminish the possibility of adaptability and responsiveness of additional or modified classes. The typological approach to classification means that an object is described by a fixed number of classes. *"The construction of typologies or classes forecloses labelling options and presets the options about the range of possibilities"* (Bowker and Star, p. 116). A *topological approach* to classification suggests a preservation of the multiplicity of meanings by means of an extendable matrix into which features of used objects can be added. Topological classification refers to the pre-emptive or open-ended capture of a recyclable object's properties, since the number of rows and columns that can be deleted or added to such a matrix is variable. Thanks to developments in information and communication technologies, many classification systems have an adaptable structure of various attributes and object classes for different purposes. As reported by van Nunen and Zuidwijk (2004), product recovery requires that more specific product attributes be added to the standard enterprise resource-planning systems, which deal with varying quality levels of used and substitute parts. However, the established categories can frame used objects in an overly strict manner. In addition, the inescapable inertia of established and learned categories already in use makes the infinite number of ontologies impractical (Bowker and Star, 1999).

Having discussed various ways in which to classify, it is now possible to define sorting rules as those that facilitate routine sorting and transformation of objects. *Sorting rules* are used for routine comparison; that is, routine selection and assignment of objects in terms of their classes in order to generate and identify uniformities and differences between these objects. Routinising of work is one of the purposes or functions of rules (Nelson and Winter, 1982). Sorting rules, together with the definitions of object classes, reference input and output values, and transformation rules, constitute the elements of a classification system, as depicted in Figure 2.9.

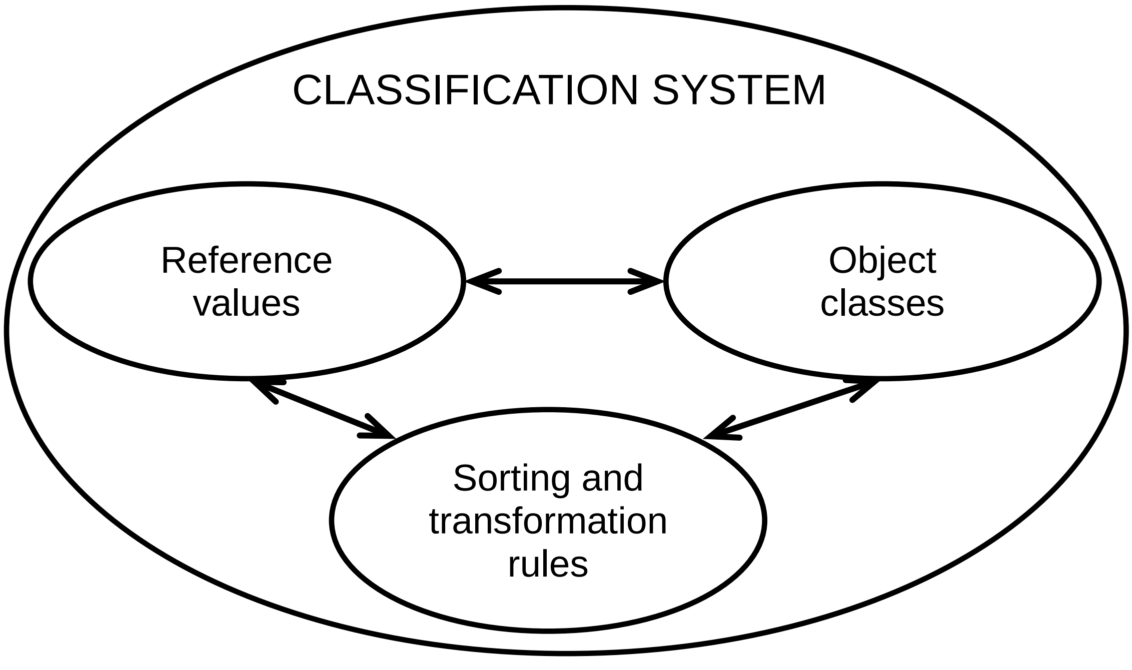


Figure 2.9 The elements of a classification system.

Sorting rules refer to decisions on the choice of topologies or properties that are used to classify objects. Once the topologies have been chosen, the reference values are assigned to these topologies. The topologies or object classes are utilised for sorting at the crossing and differentiation points so that the transformations in the network can proceed.

2.6.3 Classification systems and transformation of objects

Bowker and Star (1999) discussed the resources that move, sort, and transform information on, among other things, products between actors, and how these resources are developed and organised. Classifications as technologies are powerful artefacts that may link thousands of communities and incorporate as many boundaries. For example, a classification system that is too abstract and does not take use into account will simply fail (ibid.). On the other hand, an overly detailed or broad, or a too-limited quantity of classes pre-sets and freezes the range of categorisation possibilities, but makes the comparison and routine sortings in terms of selections and assignments easier and more organised. The challenge lies in the handling of validity and precision. Another important factor that makes the study of rules of classification systems crucial is that one of the functions of the rules is to handle uncertainty and partial ignorance, as Hayek (1982) noted. In agreement with his conclusions that rules would not exist without uncertainty, Bowker and Star (1999) claimed that an overly precise classification system would be unrealistic and counterproductive, because the advances occur through the development of tests or technologies that cause reclassifications of products. Sorting and transformation rules use the reference values belonging to the classes to sort and transform objects.

With regard to the connection of the abstract rules to valorised object classes, the choice of, for example, Incoterms determines a range of activities and resource combinations that are ruled in and ruled out. Therefore, an abstract rule refers to an unknown number of future instances, and to the acts of an unknown number of persons who are not individually designated by name, and merely states certain attributes that any such action ought to possess (Hayek, 1982). Abstract or generalised sorting and transformation rules can be organised by shaping certain factors that determine their overall features, since it is not possible to know the number, diversity, and variety of all individual elements and circumstances inside each transvection.

Callon et al. (2002, p. 198) stated that *"Defining a good means positioning it in a space of goods, in a system of differences and similarities, of distinct yet connected categories."* Classification systems, with their classes, rules and reference values, generate uniformities and differences in time, form, place and identity of objects in order to direct them to transformation facilities. Moreover, the price or cost of objects has to be determined together with data on form, time, identity, and place. Price is therefore a class of information associated with a service or product, or a blend of both, which is valorised in monetary terms. Alderson (1965) reduced price to a piece of information that usually needs to be known about the product, and Hayek (1988) referred to price as a further superimposed means of classification and, more precisely, as a means by which to classify actions. Both Hayek (1988) and Alderson (1965) treated price as one of the properties of a product that is used to register change through interactions, such as a delivery, single unit, or quantity price. For the sake of generation of economies of scale of transformations in crossing points, the quantity of uniform objects in certain classes must be known. According to Asif (2011), information in planning systems for product recovery is organised into quantity and quality aspects, among others.

Information about this physical flow must be exchanged through shared classes and corresponding values about form, time, place, identity, and price so as to define the state of a single object in order to facilitate inter-organisational activity coordination and resource combining. A group or a quantity of objects can be described by an additional row that describes their quantity dimension. This general description of object classes is illustrated in Table 2.1. Form utility has to be created by changes in form features, as in reprocessing, which can be reflected by technical drawings; time utility is created by holding inventory that is accessible to buyers; place utility is generated by transport. Changes in identity reflect the state of possession of an object. Organisations have to determine the prices, costs, and quantities related to an object or a set of objects. The bridging of time, place, form, identity, and quantity gaps has to take place in accordance with the current reference values and the desired ones. A few collective general classification, rule, information, and measurement systems for the registration of change in object classes, in order to identify uniformities and differences that direct object transformations were mentioned previously in this section.

	Example
Form	Product specifications – a reprocessor needs hardware specifications while a freight forwarder may need information about weight, length, and volume.
Time	Collection/delivery date/time; lead time between actors; current date/time.
Place	City, address, room number, distance, shelf location, inventory location.
Identity	User name, logistics service provider, and reprocessor – which all change throughout the network.
Price	The cost of products and services (salary, maintenance, and transport) to the purchasing actor is the price that the actor paid to the selling actor.
Quantity	The number of supplied and demanded objects.

Table 2.1 Object classes.

For example, with regard to product recovery, every transport buyer has to state standardised general features of remanufactured objects in terms of their weight, volume, collection and delivery location (that is, distance in kilometres). A standardised classification is more persistent than a category of a more specialised nature, although the standardised category can be adapted to suit local needs (Bowker and Star, 1999). Nevertheless, a standardised class of an object within a classification system organises and makes things work together over distances, and heterogeneous qualitative and quantitative metrics.

Selected characteristics can be used to describe other objects and aid actors in establishing uniformities and differences among objects. Some attributes of products and materials reflected in standardised object classes, such as size and weight, are more easily determined and measurable than others, and lend themselves more readily to comparison of one class with another (Alderson, 1957). Classes associated with classification systems are difficult to maintain as they have to be adapted to changing supplies, processing requirements, and customer needs. Concerning the object classes, sorting rules can be connected to classes of a more general or specific type in order to identify uniformities and differences among objects. In addition, the object classes are used to valorise and register change, and are themselves subject to change. For example, previous sub-standard raw materials may become usable due to improvements in processing, which alter reference values in qualitative and quantitative terms.

Callon et al. (2002) illustrated the changing nature of objects generated by transformations of a car in terms of its resource combinations, activity patterns and actor webs of production, distribution, and use. During the transformations, the characteristics of the object change together with the structure of information required for each actor to combine resources and coordinate activities. However, at the same time as the resource combining within the stages of product development, production, distribution, and use proceeds and alters the informational and physical attributes of an object, the resource collections and activity structures in the network are characterised by the classification, adjustment, and transformation of objects. Hence, a product and its qualities single out the actors and their resource collections, and bind them together. Table 2.2 shows how the values attached to the object classes are changed when a used object coming from a primary end user (Situation 1) comes to be recycled by a producer of raw materials with regard to manufacturing of the raw materials that it is made of (Situation 2).

	Situation 1	Situation 2
Form	Technical specifications of objects in use	Raw materials inside the objects that were in use
Time	Collection date	Reprocessing date
Place	Location of the primary end user	Location of the producer of raw materials from recycled objects
Identity	Primary end user	Producer of raw materials
Price	Price of the object in use	Price of raw materials
Quantity	Number of objects to be collected from the primary end user	Amount of raw materials in kilogrammes

Table 2.2 An example of changes of values attached to the object classes.

Classification systems, which consist of sorting and transformation rules, object classes, and reference values, exert an influence on the differentiation points and, therefore, on the objects' route, components, and raw materials between facilities for sorting and transformation. These classification systems, which are sorting resources, may be used to assign objects to different or the same transformation resources, depending on the values of the object classes, which are transmitted through the attributes and reference values of classification systems. Routines require a stable set of classifications and reference values (for example, a predetermined and desired percentage of a chemical element in an object), enabling fast identification of commonalities and differences among objects.

The function of the classification systems with their elements such as object classes, their reference values reflecting supply and demand, and associated sorting and transformation rules with regard to crossing points is to create partial uniformities by identifying similar characteristics of an object's form, time, place, and identity dimensions in the business process. Transformation rules use the uniformity of object inputs and desired object outputs in an attempt to match them. With regard to product recovery options, objects may keep their initial specifications as far as sorting and transformation rules for refurbishing are concerned.

As mentioned above, even an exact copy of a product intended for product recovery can exhibit distinctive characteristics, which are revealed at the materials differentiation points. Changes in desired attributes can suddenly redirect the path of the transvection, which could make the object, or parts of it, unsuitable for the current facility or resource collection of a single firm. This can occur at information and materials differentiation points. As stated above, if an information differentiation point is located at an earlier point in time and place than the materials differentiation point, the object can be assigned to an appropriate facility with regard to product recovery options. At the material and information differentiation points, facilities based on classification systems are used to reveal similarities and differences between objects in the form, time, place, and identity dimensions.

In summary, the right combination of assigning and selecting information about objects must be done through shared object classes. This is carried out in order to synchronise operating ratios of sorting and transformations in machines and load carriers belonging to different companies.

2.6.4 Research issues

Classification principles include those that describe an object in exclusive terms, as in Aristotelian classification, and in terms of shared features with other objects, as in prototype classification. With regard to the management of information, topological classifications imply an extendable and adaptable matrix by which objects are elucidated, whereas typological classes entail a fixed number of features. With regard to the endurance of an object's characteristics, the long-term features are described by tightly coupled classes, while the properties with short longevity are defined by the loosely coupled categories.

Coordination of activities and combining of resources can be achieved through abstract/standardised and specific rules, and direct instructions. All three kinds of rules complement each other and may alter the form, as in the case of regulation or deregulation. A classification system includes a set of interrelated and consistent sorting and transformation rules as well as containing classes, which are used for sorting and as interfaces. Organisation of information exchange with regard to the object classes in reverse physical flows is of great significance to inter-organisational handling of uncertainty, activity interdependencies, and resource combinations. The provision of data to classification systems is conducted via the utilisation of information systems.

Sorting rules are utilised at the crossing and differentiation points to classify information about objects in order to coordinate activities that direct objects scale efficiently into adequate resource combinations belonging to various actors in the network. These rules also guide the direction of the objects through the facilities involved in product recovery. On the other hand, transformation rules are utilised in the matching and changing of qualitative and quantitative reference values, and limits belonging to the classes that are determined by sorting and sorting rules.

The focal research issue in understanding the influence of the classification systems on resource combining and activity coordination refers to the management of objects in the product recovery network. This is because this study revolves around the concept of interlinked transvections of distinctive product recovery options and activities performed by resources on objects by a network of organisations. In order to investigate the impact of the classification systems with their rules and instructions on organising product recovery, the focal research issue can be answered by three questions:

- How do sorting and transformation rules contribute to activity coordination and resource combining?
- What classification principles are applied at the crossing and differentiation points?
- How does information impact on classification systems and cause changes in the object classes related to time, place, form, identity, quantity, and price?

To summarise, these research issues were outlined so as to enable investigation of the impact of classification systems on inter-organisational activity coordination and resource combining. Having discussed the issues associated with the three separate dimensions of the Industrial Network Approach and the classification systems, these will now be united in the concluding part of this chapter via a description of a framework for analysing the organising of product recovery.

2.7 A framework for analysing the organising of product recovery

The aim of this thesis is to study the organising of product recovery from an inter-organisational perspective, through the development of a framework that permits analysis of business relationships in such structures. Based on this aim, the theoretical frame of reference of the thesis has been described in this chapter. The Industrial Network Approach is used as a main theoretical base in the study. This theoretical approach makes it possible to study product recovery in three separate, but interrelated, fundamental layers based on the three network dimensions of activities, resources and actors. With regard to organising product recovery, this examination can therefore be approached in three ways: organising product recovery in the activity pattern, in the resource constellation, and in the web of actors. Apart from the discussion about the layers of the Industrial Network Approach, the role of classification systems in organising has been elaborated upon in this chapter. After each section, which described concepts related to the three layers and classification systems, research issues were pointed out. These issues and the framework are summarised below and in Figure 2.10, which shows that actor interaction and classification systems play an important role in the development and choice of the ways of activity coordination and resource combining. Actors position and organise their resource collections and activity structures by means of interaction via classification systems.

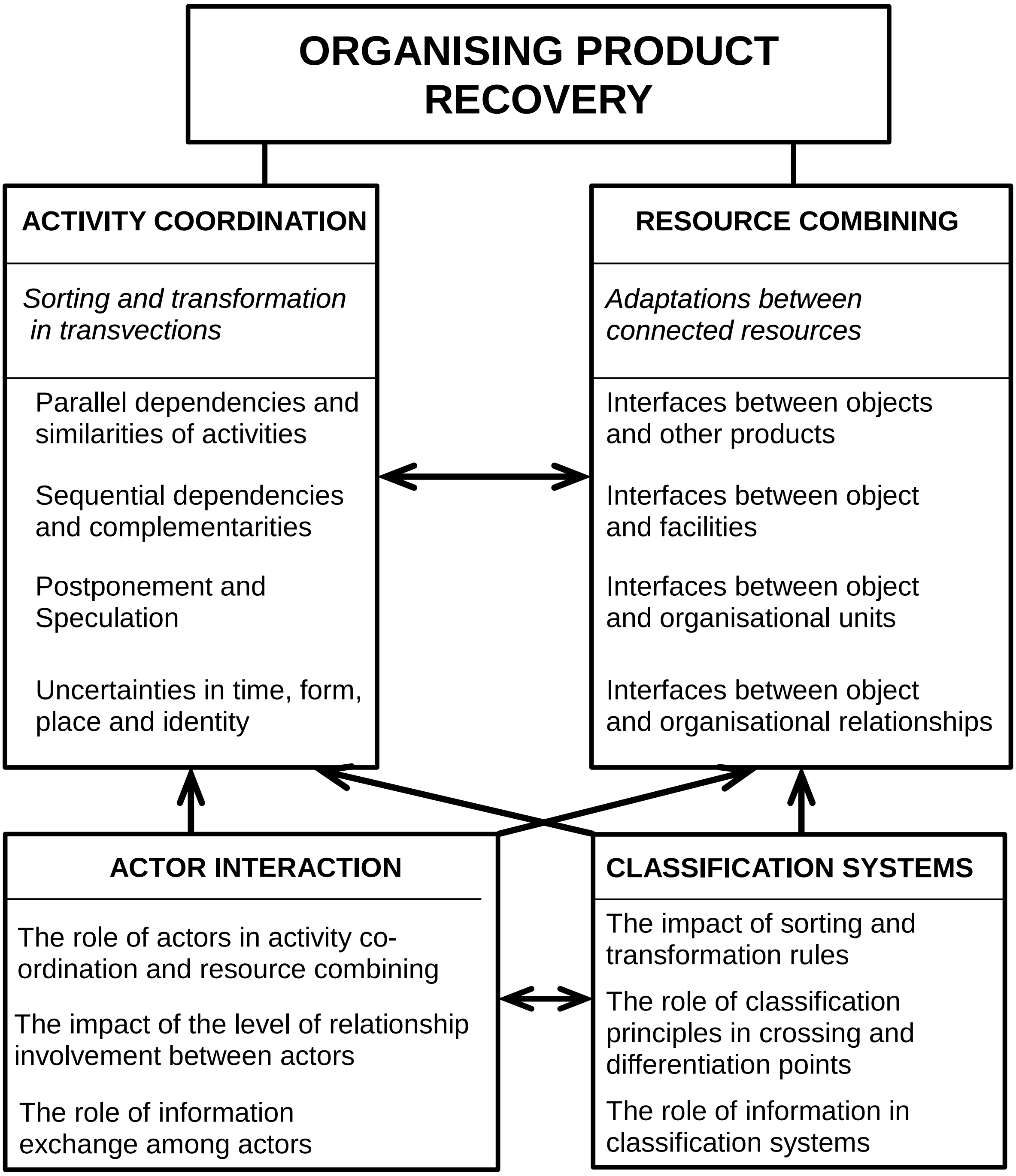


Figure 2.10 A framework for analysing the organising of product recovery.

In the activity layer of the Industrial Network Approach, the central issue is to identify transvections that represent various forms of product recovery options (from reuse to recycling), and activity interdependencies, combined with distinctive ways of applying the principles of postponement and speculation. The sorting and transformation activities in these transvections are thus analysed with regard to the occurrence of:

- Parallel dependencies and similarities.
- Sequential dependencies and complementarities.
- Postponement versus speculation.
- Uncertainties as to time, place, form, and identity.
- Crossing and differentiation points.

The main issue in the resource dimension is to analyse resource combining, adaptations and tensions by exploring the interfaces among resources along the transvection, including:

- Interfaces between the object and other products.
- Interfaces between the object and facilities.
- Interfaces between the object and organisational units.
- Interfaces between the object and organisational relationships.

Organising product recovery by coordinating activities and combining resources is the task performed by actors. Hence, for the actor layer, the key issue is to identify and explore relationships between organisations in product recovery arrangements, and the roles of actors that are involved in activity coordination and resource combining in transvections. The specific issues in the actor layer concern:

- The identification of actors who coordinate activities and combine resources.
- The analysis of how interaction and relationship involvement are used in activity coordination and resource combining.
- The analysis of how different kinds of information exchange affect activity coordination and resource combining.

When it comes to the impact of classification systems on organising product recovery, the main issue is related to activity coordination and resource combining. With the intention of studying the effect of the classification systems on activity coordination and resource combining, the following issues are key:

- How do sorting and transformation rules contribute to activity coordination and resource combining?
- What classification principles are applied at the crossing and differentiation points?
- How does information impact on classification systems and cause changes in the object classes related to time, place, form, identity, quantity, and price?

3 METHODOLOGICAL CONSIDERATIONS

In the first part of this chapter, the actual research process is described as it relates to the iterative and emergent development of the case studies and the analytical framework. The research method applied is presented in the second part of this chapter, including an explanation of choices regarding the research approach, case selection, and methods for data collection. Finally, the quality of the study is evaluated.

3.1 Research process

In 2009, I took up my position as a doctoral student. This meant that I became part of the Division of Industrial Marketing at the Department of Technology Management and Economics at Chalmers University of Technology.

At the same time as I commenced my employment, I became involved in a research project called Sustainable Logistics. The project, entitled Integrated Logistics Development for Sustainability and Competitiveness (henceforth referred to as Sustainable Logistics), which is briefly described below, involved organisations besides those from the academic world, including the Swedish Governmental Agency for Innovation Systems, Logistics Transport Cluster (LTS), Volvo Logistics, Schenker, Stora Enso, Region Västra Götaland[27] (hereafter RVG), and City of Gothenburg Traffic Division.

3.1.1 Sustainable Logistics project

The Sustainable Logistics project was performed in collaboration with six doctoral students and the same number of senior researchers from the Division of Industrial Marketing and the Division of Logistics and Transportation at Chalmers University of Technology, and logistics researchers at the School of Business, Economics and Law at the University of Gothenburg. Sustainable Logistics had a general focus on operational efficiency and environmental sustainability within the field of transport-related logistics.

Taking into consideration the assumption that there are opportunities for transport buyers, transport providers, and transport operators, as well as society at large, to move in the direction of efficient and sustainable logistics solutions, the project covered six areas of research. These included operational transport efficiency, effective transport and logistics solutions from a Third Party Logistics Provider’s perspective, requirements set regarding transport by the buyer, business opportunities related to sustainability issues, analysing current measures aiming at the sustainable transportation of goods from a systems perspective, and sustainability in the making and distribution of domestic biofuel. My

[27] Region Västra Götaland, a county council in charge of the regional companies in the public sector.

research area dealt with how companies collaborate to take advantage of business opportunities related to sustainability issues in logistics. The development of the case studies and the analytical framework (which is an important output of this research) that was used to explore this research area are discussed in the next section.

3.1.2 Development of the case studies and the frame of reference

As the research area that I planned to investigate dealt with inter-firm cooperation, even at the beginning of the project, I had to find a match between the empirical and theoretical world; that is, between the theoretical foundations and my research topic. On the theoretical side, related to the qualitative analytical foundations of this thesis, the Industrial Network Approach was chosen because it has a rich set of concepts with regard to resources, actors, and activities compared to other theories, which usually revolve around one of these aspects. Early on in my association with the Division of Industrial Marketing at Chalmers University of Technology, I was introduced into the theoretical pillars of the Industrial Network Approach by reading three textbooks (Ford et al., 2003; Jahre et al., 2006; Ford et al., 2007). Regarding empirical enquiry, one article (Sharma et al., 2010) that was handed to me prior to its publication was the most significant guide in my initial search for appropriate industrial structures under which to explore my research area. These references were very influential in my selection of the empirical area of interest, and the analytical framework of the study.

Since the textbooks covered all three layers of the Industrial Network Approach, activities, resources, and actors – I had all of these three lenses in mind during the collection of data. In particular, the ARA model, which integrates all of the dimensions into a systemic whole, influenced my perception of the business world. This was connected to the nature of the research project, which itself required a holistic theoretical perspective. Since the Industrial Network Approach (e.g., Håkansson and Snehota, 1995; Håkansson et al., 2009) takes into consideration the longevity of business relationships between organisations in line with the long-term perspective of sustainable development, I chose it as a base for my frame of reference.

Another reason for choosing the Industrial Network Approach relates to the fact that firms and organisations, are generally embedded in networks of relationships. It is the interdependencies between suppliers, manufacturers, logistics service providers, intermediaries, and customers that constitute the structure of the network. These theoretical interests had a major influence on the research process of this thesis from the very first day, as the study is about inter-organisational coordination of activities and resources.

With regard to the selection of cases, the Sharma et al. (2010) reference wakened my interest in reverse logistics of PCs, as it empirically covered product recovery arrangements in this business sector. I was briefly introduced to the research field of reverse supply chain management during the courses I took at master's level. My main supervisor, Kajsa Hulthén, introduced me to the research area of Closed Loop Supply Chain Management during the spring of 2009. Many of the articles considered in both her and my literature review are used throughout the thesis. Since I considered this research subject to be very closely connected to sustainability and logistics, I made it a suitable point of departure for this thesis. Therefore, my main supervisor and I performed literature reviews on the subject of Closed Loop Supply Chain Management. In addition, I decided to contact companies involved in the collection, distribution, and recycling of electronics, including a collector/recycler (Renova), a PC manufacturer (Dell Computers, henceforth referred to as Dell), and their Third Party Logistics Provider (Schenker).

A doctoral colleague from the Division of Logistics and Transportation, who was a manager at Schenker, helped me to contact the person responsible for logistics solutions offered to Dell in the Nordic region. This interview dealt with general and broad areas of business that connected environmental aspects with logistics. One of the topics concerned reverse logistics, which I wanted to explore further in the empirical world. I therefore decided to contact Renova as I thought that this firm could give me more elaborate answers on the processes that are closely related to the recycling of electronic waste.

The interview at Renova provided me with a general overview of the recycling industry for electronic and electrical products, in terms of the largest actors and processes involved in these structures. I noticed that products themselves are adapted with regard to forward physical flows, as many operations in reverse physical flows are manual and the dismantling of products takes a great deal of time. In addition, I observed the changing features of products at Renova's facility. Renova are paid per kilo of categorised goods, depending on the properties of the raw materials that go into manufacturing the new products.

These circumstances enabled me to see a connection between the empirical world and the analytical tools related to the resource dimension of the Industrial Network Approach. Because this interview was conducted concurrently with my attending a course based on a book about resource combining in logistics (Jahre et al., 2006), I decided to include the 4R model and the notions of resource adaptations and tensions in the thesis's frame of reference. The four resource entities of the 4R model – products, facilities, organisational units, and organisational relationships – were discernible at Renova's facility, as well as in collaborations between companies that deal with other product recovery options.

After the interview with Renova, my search for appropriate research companies, based on Sharma et al. (2010), led me to Dell. My first interview with the company was set to take place at Dell's local sales office in the spring of 2009. During that spring I was given a doctoral dissertation (Hulthén, 2002), which turned out to be a major source of inspiration for the analytical framework of this thesis, besides the analytical tools stemming from the literature on the Industrial Network Approach.

As I was reading the dissertation (Hulthén, 2002), the concepts of object, sorting and transvections caught my immediate attention. I had already performed a minor literature review on reverse logistics, which familiarised me with the definitions of activities in this particular research field. In several frameworks for the analysis of this kind of logistics system, the activity of sorting and classification was explicitly stated as a crucial operation for routing of products, parts, and raw materials inside the companies, as well as in inter-organisational physical flows. At that moment, it seemed that the theoretical representation of transvections and sorting, in combination with the principles of postponement (Alderson, 1950) and speculation (Bucklin, 1965), could be applied to the study of product recovery milieus. An initial tool to select, describe, and analyse different transvections in this thesis was generated at this point in time. Furthermore, selection of the actors and, therefore, transvections was based on the availability of information that the interviewees provided. The aim was to describe transvections that included all product recovery options, such as remanufacturing, refurbishing, recycling, incineration, and landfill.

Following the interview with Dell in Stockholm, I learned more about transvections from the original sources (Alderson, 1965; Alderson and Martin, 1965). In this manner, the interview with Dell proved to be a significant moment with regard to the analytical framework and the empirical inquiry of the thesis.

The interview with the Sales Manager at Dell in Stockholm and other contact persons at the company provided connections to other actors that are involved in processing used PCs from RVGs. When I introduced the project that I was part of and the actors that were involved in it, including RVG, the Sales Manager concluded that it would be appropriate for me to study the product recovery arrangement for the collection and reprocessing of their PCs, which are replaced by Dell on a three-year basis. Dell helped me by providing access to the firms that are involved in this network on their behalf. In 2010, I made some observations of the operations of IT Logistic and Igus Data. Besides conducting observations, I interviewed companies that were planning logistics and selling refurbished PCs.

At the time of the initial interviews with Dell, I attended a doctoral course entitled Dissertation Analysis. The aim of the course was to introduce doctoral students to techniques for the examination of scientific work with a focus on doctoral dissertations. One of the course seminars dealt with a dissertation that covered the topic of inter-organisational coordination of activities. The framework of the dissertation (Dubois, 1994) and further developments (e.g., Håkansson et al., 2009) provided me with supplementary tools for the examination of activity interdependencies, in terms of balancing differentiation and customisation with economies of scale (that is, activity complementarities and activity similarities). I viewed these concepts as very suitable for the theoretical framing of the direction of activities towards actors that perform distinctive product recovery options.

Thus, analytical tools associated with the activity layer of the Industrial Network Approach shaped my understanding of the product recovery processes between 2009 and 2011, as I conducted several interviews and observations with firms that are involved in the collection, logistics, reprocessing, and distribution of PCs that Dell leases to RVG. The active role of RVG in the disposal and collection processes associated with used PCs made them a suitable point of departure in this network and case, following discussions with my supervisors in the autumn of 2011. From a theoretical perspective, this delimitation or bounding of the case seemed appropriate in terms of theoretical contributions of the thesis, as research in reverse logistics does not usually take the perspective of the disposer. Furthermore, in the literature on reverse logistics and Closed Loop Supply Chain Management, disposers are often described as passive actors and are largely considered external parties in reverse logistics systems.

To further investigate reprocessing, I interviewed Igus Data, the company that refurbishes the used PCs coming from RVG, and took notice of the varying level of involvement and differentiated features of business relationships they handle. As a result of this observation, I undertook literature reviews, and, after consultation with my supervisors, decided to include the actor dimension of relationships in the thesis's frame of reference. In the spring and autumn of 2010, I undertook literature studies concerning the actor layer of the Industrial Network Approach, in order to acquire analytical tools for the examination of inter-firm relationship behaviour.

As my literature reviews of the actor layer of the Industrial Network Approach continued, I also searched the Internet for industry-related articles on Swedish companies involved in product recovery settings, and came across a refurbisher named Once Again. At an interview conducted in 2009 with the Managing Director of Once Again, I learned that the largest distributor of IT-related products, Atea Logistics, whose managers my supervisors were acquainted with, is also involved in refurbishing PCs. I decided to contact Atea Logistics, the company that eventually became the focal actor of the second case study of this thesis. The firm and its network contributed to my understanding of the phenomenon of organising product recovery, as they offer differentiated logistics services to disposers, and are themselves involved in refurbishing products. The case study about Atea Logistics and its partners introduced another kind of variety into the thesis, as that company, in cooperation with Schenker, Eurovironment, and Jemacon Logistics, offers a set of standardised solutions with regard to collection processes.

All in all, I ended up with two case studies based on different perspectives of the archetypical roles of actors in product recovery arrangements, which broadened my research process by adding different perspectives. In other words, RVG as the focal actor highlighted the role of the disposer in the first case study, whereas the second case study assumed the perspective of a reprocessor, Atea Logistics.[28] Moreover, Atea Logistics acts as an organiser of the activities involved in this context, as they develop solutions that direct the path of the collected products toward alternative product recovery options. This is in contrast to the first case description and the actors involved in that case study, which concentrate on two product recovery options: remanufacturing and refurbishing.

Towards the end of 2010, joint efforts related to the handling of used PCs from RVG, and the interviewed logistics and reprocessing companies, came to an end. This temporal demarcation made it easier to observe the case boundaries and to detect a distinction between the case studies. Thus, most of the interviews from that moment on were conducted with Atea Logistics and the actors that are closely connected to the logistics services provided by this firm. I therefore concentrated my data collection efforts on the second case study, which focused on Atea Logistics, a company that was initially interviewed in the spring of 2010. A year later, I conducted additional interviews with Atea Logistics, as well as with their partners, Eurovironment and Inrego.

Data collection was finalised in the autumn of 2011, as the final follow-up interviews with Schenker and Atea Logistics concluded. Since the concepts and tools for the analysis of activities and resources were developed towards the end of 2011, I turned my attention to the models associated with the actor layer of the Industrial Network Approach. In that regard, after consultation with my supervisors, I decided to conduct a literature review on the level of involvement in business relationships and the positioning of actors in the network.

As Huge-Brodin (2002) analysed network positions in the logistics systems for recycling, her dissertation was included in the literature review concerned with the actor dimension of the Industrial Network Approach in the spring of 2012. I had previously read the dissertation in 2010, but now that my frame of reference was in its final phase of development I could use the findings of this dissertation more appropriately, in relation to the positioning of actors in this thesis. This last literature review meant that all three network dimensions could now be fitted into the frame of reference of the licentiate thesis for the analysis of how actors organise activities and resources in product recovery structures embedded in networks.

Having finished the licentiate thesis, the research process continued empirically and theoretically in accordance with suggestions by colleagues and supervisors and the last section of the licentiate thesis (Insanic, 2012) about further research. The theoretical quest went in the direction of searching for literature on sorting/classification, and classification systems (Bowker and Star, 1999) and rules (Hayek, 1982, 1988; Brunsson and Jacobsson,

[28] The thesis first presents the second case study in Chapter 4 while some of the data from this chapter is scrutinised in the analysis of the first case study in Chapter 7.

2000; Ostrom, 2005). Both I and one of my supervisors, Lars-Erik Gadde, performed literature reviews in 2013 and 2014 to update our theoretical knowledge of the research area and to confirm the fact that there was a need for more qualitative research about product recovery. The concepts used for handling different transvections in terms of the points where and when economies of scale are generated, and where and when counterpart adaptations were created, were inspired by the frameworks of Hulthén (2002), and Mason-Jones and Towill (1999). The latter reference was used to induce variety in the selected transvections with regard to the points in time and space at which the activities become complementary, and where differentiation occurs.

From the perspective of data collection, recycling was in focus since I was given advice by my opponent at the licentiate seminar to find out more about the topic. To this end, I interviewed two firms who process raw materials from IT equipment: Sims Recycling Solutions, interviewed in the autumn of 2012, and Boliden Rönnskär in January 2013. These were influential in the selection of analysed transvections, as additional actors, their resources, and activities could be added into the analytical description of transvections. These empirical findings helped me to order transvections according to the way in which they are performed by various supplementary firms. In the autumn of 2012 I conducted an additional interview with the focal firm of the case study, Atea Logistics, from the reprocessor's viewpoint, and paid a visit to their refurbishing facilities. The reasons for my visit were to clarify some aspects which were still unclear, and to gather information using a theoretical approach anchored in classification systems and rules. This meant that I asked questions with regard to the use and design of their planning and article/order number systems. Altogether, these empirical and theoretical efforts resulted in this thesis; the research method used is theoretically portrayed in the next section.

3.2 The research method

As outlined in the section on the research process, this thesis was developed through a continuous alternation between the analytical framework and the empirical world. This procedure for conducting research has been defined as systematic combining (Dubois and Gadde, 2002), and is discussed in section 3.2.2. However, first of all I will turn to the question of the appropriateness of using the case study approach as a research strategy.

3.2.1 The case study approach

Recent reviews of Closed Loop Supply Chain Management research (Souza, 2013; Sheriff et al., 2012), which have demanded empirically based qualitative research involving analysis of real situations/settings, contributed to the selection of the qualitative case study research method for data analysis and collection. A rationale for the choice of a qualitative case study design in this thesis is grounded in the literature on research methodology (e.g., Yin, 2003).

Yin classified commonly used research strategies and methods in social sciences as surveys, case studies, longitudinal and ethnographic studies, action research, "true" experiments, and historic and archive analysis. According to Yin, two conditions determine the choice of a research strategy: the extent of control an investigator has over actual behavioural events (where a low level of control is characteristic of case studies), and the degree of focus on contemporary, as opposed to historical, events (where a high degree of focus on contemporary events is typical of case studies). In agreement with Yin's guidelines, the following conclusions with respect to the choice of research method were drawn. The case study approach was deemed suitable for this study because this thesis mainly deals with the identification, description and explanation of contemporary organising in business relationships in the product recovery context of networks. Furthermore, I had no control over behavioural events. In line with this reasoning, Correa (1992) argued that case research is the most appropriate research design when there is a need to build theory, compared to experiments, surveys, and action research.

Since I focused from the outset of the study on how companies, through cooperative organising, can take advantage of business opportunities related to sustainability issues, I believed that a qualitative case study design would be an appropriate research strategy in an empirical and theoretical sense. From the empirical perspective, the main reason for the choice of this method was my conviction that business relationships and inter-organisational interaction are phenomena that cannot be described or measured quantitatively, due to their inherent complexity. Knemeyer et al. (2002) claimed that a qualitative methodology provides additional opportunities to identify critical issues, and allows for a deep, probing analysis when compared to quantitative approaches. Furthermore, extant research on product recovery has been heavily influenced by survey-based research and quantitative network models (Gobbi, 2011). In agreement with this, Govindan et al. (2013, p. 330) claimed, in their discussion on inter-organisational coordination, that *"while complex methodologies have been used on forward supply chains, only mathematical approaches have been applied on the reverse logistics settings"*. This served as an additional motive for the use of a qualitative case study in this thesis. As stated above in the introductory chapter, very few researchers have used theories (such as Transaction Cost Economics and Resource Based View) as explanatory tools by which to analyse product recovery, and when it has been used it has been in a firm-, dyad-, or supply-chain-centric context. Ryan et al. (2012) and Insanic and Gadde (2014) are two exceptions to the rule when it comes to theoretical studies of the sustainability and ecological aspects of business networks. Therefore, Winter and Knemeyer (2013, pp. 33–34) advocated additional *"transfer of existing theories and approaches to inquiry in this area"*.

Dubois and Gadde (2002) acknowledged that qualitative case studies provide unique means of developing theory by utilising in-depth insights of empirical phenomena and their context. In order to achieve an understanding of business relationships in networks, it is crucial to study the interplay between three elements for qualitative analysis and collection of data in the

Industrial Network Approach. The case study research methodology was chosen for this thesis, as one of the ways of fulfilling its aims was to conceptually describe activity coordination, resource combining, information exchange, and actor interaction within the context of product recovery settings in networks. More precisely, the research questions are directly connected to this analytical framework, and deal with issues of how actors use classification systems to perform and coordinate activities, and utilise and combine resources in product recovery arrangements.

Dubois and Araujo (2007) stated that case studies fit well with interactions, relationships and dependencies, which are the basic units of analysis of the Industrial Network Approach. The complexity of industrial networks requires a methodology and data collection process that parallels the connectedness and dynamics of these milieus. This can be explained with reference to the embededdness of business relationships in networks, which causes events to spread in a chain of consequences in such a dynamic manner that it is impossible to delimit the case boundaries in time or scope in advance. This process of case study bounding and case selection within this thesis is discussed below.

Selecting cases

The selection of cases in this thesis evolved gradually through interactions between the collected data and the analytical framework. According to Dubois and Gadde (2002), the way in which boundaries in the empirical world are expanded is of major importance, because it determines what will be found out. In the network context, it is common or natural to study interactions between several supply chains and distribution channels within a certain industry.

From the theoretical viewpoint, the selection of case studies was based on the concept of transvection and its focus on the objects in question. In other words, the objects – used PCs – were the focus of the analysis of empirical findings through the application of all three layers of the Industrial Network Approach in this thesis. The PC industry was selected at the beginning of the study, as the decision to contact actors involved in this business was influenced by an article about business-to-business marketing and sustainability (Sharma et al., 2010). In addition, the PC industry generates very large and increasing waste quantities (Thomas et al., 1999; White et al., 2003; Lee and Dong, 2008), which makes it very relevant to study from the viewpoint of sustainability.

In this thesis, two case studies of networks surrounding two focal actors gradually emerged as the theoretical frame of reference, and their collected data interacted. Both case studies provide empirical descriptions of how product recovery can be organised by disposing/supplying, collecting, sorting, reprocessing and redistributing firms.

First and foremost, two case studies were empirically identified, owing both to the different periods during which data collection took place, and the intention to describe diversity from the disposer's and the reprocessor's perspective. The case study description from the disposer's (RVG's) perspective was completed towards the end of 2010, while the case study description from the reprocessor's perspective was finalised in the winter of 2014.

As stated above, the first case study relates to the disposal and handling of used PCs from organisational units of RVG in Sweden. It describes how RVG organised the handling of its obsolete IT equipment with its partners. The second case study demonstrates how a distributor of new IT products, Atea Logistics, works together with its customers, suppliers and other parties in product recovery, with a focus on handling used PCs.

In accordance with the discussion of Handfield and Melnyk (1998), I employed two focused multi-site case studies in order to develop theory by identifying and describing key variables or concepts and linkages between them. Thus, organising of product recovery is elaborated upon and scrutinised with reference to the activity pattern, resource constellation, and web of actors.

Although Denscombe (1998) and Eisenhardt (1989) stated that multiple case studies strengthen the chain of evidence and increase the generalisability of conclusions, the aim of the two conducted case studies was not so much to draw general, cross-case conclusions, as to illustrate diversity in the organising structures associated with product recovery arrangements. Variations in transvections or the activity structures of both case studies related to principles of postponement/speculation, activity interdependencies, crossing and differentiation points, alternative product recovery options, and the involvement of various types of actors. With regard to the resource dimension of the ARA model and the 4R model, two different objects, with their interfaces in terms of classification systems and rules with facilities, organisational units, and organisational relationships, were analysed: a desktop in the case study from the disposer's perspective and a laptop in the case study in which the reprocessor was a focal actor. In the actor layer, the centre of attention was, to a minor extent, a particular product, compared to the other two layers. This meant that analysis focused on how behavioural factors such as the level of involvement, positioning of actors, cooperation and competition, and the structure of information exchange influenced the overall efficiency and effectiveness of activity coordination and resource combining and recombining.

To summarise, both empirical observations and the analytical framework gradually influenced the bounding and selection of case studies. This interplay between the case and the framework, called systematic combining, is discussed in the next section.

3.2.2 Systematic combining – an abductive approach to case research

Within a general research approach, there are two methods that can be seen as each other's counterpoints: the inductive and the hypothesis deductive method (Wallén, 1996). The choice of research method concerns the interplay between theory and empirical findings. Induction means making general and theoretical conclusions on the basis of the material gathered. In contrast, the hypothesis deductive method is an approach that creates theoretical hypotheses and tests them against the empirical findings to see whether they can be verified.

In this study, a combination and iteration of the inductive and the hypothesis deductive approach, called abduction, is used. Abduction entails alternating back and forth between theory and empirical findings (Alvesson and Sköldberg, 1994). Alvesson and Sköldberg also argue that abduction reflects the true nature of the research process in comparison to either pure induction or deduction. The actual research process applied in my work with this dissertation was abductive, while the structure of the manuscript is deductive. The study was deductively based on the Industrial Network Approach, which helped me to conceptualise, organise, and analyse the research issues and empirical data from the start. However, the inclusion of theoretical concepts regarding classification systems and principles, as well as rules, was inductive. This means that the empirical data directed my attention to search for adequate theories in order to analyse my case studies.

Systematic combining (Dubois and Gadde, 2002) is an abductive approach to the case study research process in which empirical findings inspire successive changes of viewpoints with respect to the theory concepts, and vice versa. This results in a continuous reorientation of the analytical framework and research issues. Systematic combining emphasises two main processes that affect the research process through continuous interaction between the case study, the analytical framework, the empirical world, and the theory. These two processes, depicted in Figure 3.1, are *matching*, and *direction and redirection*.

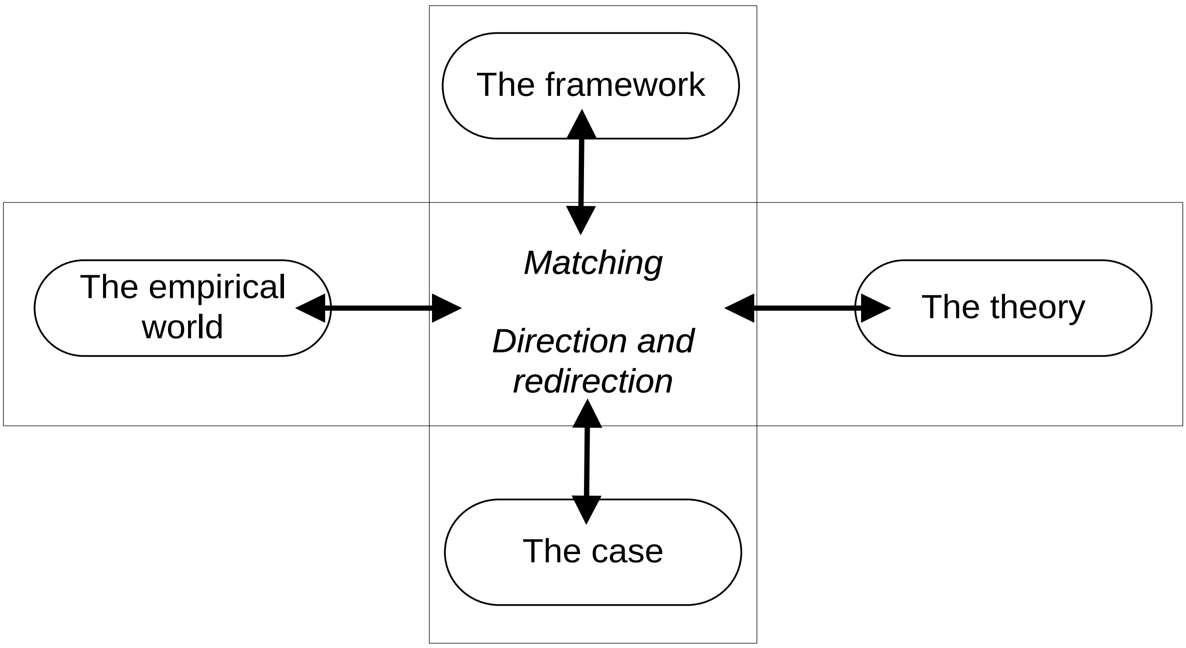


Figure 3.1 Systematic combining (Dubois and Gadde, 2002).

Matching between the development of the case and the framework is dependent on matching between the empirical world and the theory. This process of matching is connected to the direction of the study or, in other words, the development of the course or focus of the study. Direction/redirection refers to continuous changes to a researcher's view of reality, which can elucidate new research issues. In turn, this process is facilitated through the matching process (ibid.).

As outlined in the section on the research process, I read the current literature about sustainability and business relationships, reverse logistics, and the Industrial Network Approach before conducting the initial interviews. More precisely, the work in this project started with an initial exploratory literature review of the Industrial Network Approach, in order to establish a platform that would enable me to identify the structures and patterns related to organising product recovery in the field. At the beginning of the research process, I conducted literature reviews on the Industrial Network Approach, which served as the theoretical base of the study. This is in accordance with suggestions of Dubois and Gadde, who argued that theoretical underpinnings or the analytical framework of the study is one of the cornerstones of systematic combining (ibid.).

Then, following the first literature review on reverse logistics and Closed Loop Supply Chain Management, I decided to integrate the concept of transvections and the concept of the object into the frame of reference due to the importance of sorting in empirical findings during the primary data collection process. The reason for this addition of analytical tools in the framework was that the concept of transvection grouped all activities into two fundamental processes – sorting and transformations – performed by a number of firms within the system, which are more parsimonious in classifying activities but more conceptually rich than Porter's Value Chain, which classifies a set of predetermined activities of a focal company into primary and supporting activities (Priem et al., 1997).

I was aware of the importance of sorting during the remaining interviews of the research process, and as my literature review on reverse logistics continued. These first interviews also contributed to the application of concepts and analytical tools, such as the 4R model, and resource tensions and adaptations, as these were recognised to be relevant in the empirical world. An example of the tensions was displayed in the troublesome dismantling operations. As mentioned earlier, during the development of the case studies, I noticed that the features of relationships influenced activity coordination and resource combing, which led to studies of the behavioural dimensions of the actor layer of the Industrial Network Approach, in general, and with regard to product recovery, in particular.

As stated above, when the licentiate thesis was published in 2012, one of my supervisors, Lars-Erik Gadde, and I conducted literature reviews in 2013 and 2014 to keep us updated on the current issues within the research area. Further research issues outlined in the licentiate thesis made me search for theories and concepts (e.g., Hayek, 1982; Bowker and Star, 1999; Brunsson and Jacobsson, 2000; Ostrom, 2005) that could improve my theoretical framework. After this theoretical inquiry I collected data with these new theoretical foundations in mind.

In summary, the theoretical framework and the case studies within this thesis emerged through interaction between the empirical world and the theoretical assumptions. The acquisition of theoretical knowledge and analytical tools occurred simultaneously, as the empirical observations of reality took place through interviews, observations, study visits, and documents. How these empirical observations were collected is described in the following section.

3.2.3 Collection of primary and secondary data

Creswell (1994) described a qualitative case study as an inquiry process, conducted in a natural setting with the intention of understanding a social or human problem, through building a complex, holistic picture, formed with words, and reports of detailed views of informants. Arguing for a combination of the Industrial Network Approach and the case study research approach, Easton (1998) recognised that studies of complex, intertwined layers of actors, resources, and activities across organisational boundaries require the collection of multiple forms of data that cannot be easily standardised or aggregated as in a quantitative research design. In addition, various combinations of quantitative and qualitative data collected from interviews, databases, archives, and observations represent one of the strengths of the case study approach (Eisenhardt, 1989). Thus, in this thesis, both quantitative and qualitative data has been collected and analysed.

Besides grouping the data into a qualitative and quantitative form, information that has been collected during a research project can be classified as either *primary* or *secondary data* (Arbnor and Bjerke, 1994). *Primary data* is collected for a certain purpose; for example, information from interviews, which will be used for a certain study. Methods of primary data collection include observations, interviews, and experiments (ibid.). *Secondary data* is information that is often produced for a reason other than the purpose of the current study. Examples of secondary data include information from literature, earlier research, and official statistics. According to Yin (2003), there are two types of secondary data, namely documentation (such as memoranda, agendas, minutes of meetings, administrative reports, formal studies, and newspaper articles) and archival records (including organisational charts and budgets, maps, personal records, and survey data).

The possibility of using several data collection methods and sources during a study is one of the greatest advantages of the case study research strategy (Denscombe, 1998). Therefore, several sources of data, both primary and secondary, have been utilised in this investigation.

A case study can include data from public and private archives, as well as from direct observations and systematic interviewing (Leonard-Barton, 1990). A similar classification was made by Bryman and Bell (2007) who stated that qualitative collection of data is conducted by interviewing individuals or groups; observation; and collection of texts and documents.

To achieve the aims of the study, product recovery arrangements in networks involving disposers, collection and transportation companies, reprocessors (such as recyclers or remanufacturers) and intermediaries have been examined. Information regarding the resources and activities that these actors handle has been collected via interviews, participative observations, and through the study of documents and secondary evidence.

Yin (2003) explained that different data collection methods and the use of primary and secondary data in case studies is one of the strengths of case studies. This data can be gathered from documentation, interviews, physical artefacts, archival records, and direct observation. Documents are most often accessible as texts (in printed form), but they can also take the form of electronic files (Flick, 2009).

In this thesis, the main source of qualitative and quantitative data in terms of secondary data includes administrative reports, formal studies, newspaper articles and archival records, such as organisational charts, process maps and administrative lists. It has been interesting to note that these charts and procedures only mirror general descriptions of processes, whereas reality exhibits a large number of modifications in the resource and activity structures that are conducted on a daily basis. Another disadvantage of secondary data is that these documents are produced for purposes other than to research a particular issue (Yin, 2003).

3.2.4 Observations

Direct observation usually means live observations of current events (Flick, 2009). Less formal, direct observations can be made during interviews or field trips. Non-participant observation enables the observer to find out how something actually works or occurs (ibid.). The observer can obtain a clear picture of social behaviour without a large amount of interaction with people. Participant observation is a type of data collection in which the researcher is not a passive observer, but assumes a role in the studied sequence of events. The observation periods might be a problem for the observer, since he/she has to select or be invited to the places where the process of interest can be observed, on the dates when this will occur (ibid.).

During my research I have studied different processes, such as reprocessing, and delivery of new, and collection of old, products. For a number of hours on several occasions I studied and participated in the delivery of the new products and collection of used products. I even performed some minor setting-up of products (specifically, PCs) onsite, in addition to conducting observations of a more passive type with respect to storing, transporting, and reprocessing products. Regarding the remainder of the actors, such as managers, whom I interviewed, it can be said that they usually had from one to three hours of time available for the interviews, which explains why participant observation was not possible to a larger extent on every occasion. Most observations have been confirmed using additional data via personal contact, e-mail, and telephone.

3.2.5 Interviews

Interviews can be structured, unstructured, or semi-structured (Bryman and Bell, 2007; Yin, 2003). As the research process of this thesis progressed, the interview questions became increasingly structured. Although this was not a completely linear process, the interview guides became more focused as the work with the case studies and the theoretical frame of reference continued. In other words, the topics that were discussed became more focused, deeper and narrower, as I got a better grip of my interest and the issues that were relevant in the field. However, I still tried to be open-minded in order to perceive facts that I had not focused on previously. I therefore tended to eschew questions with a small number of answer alternatives, and instead formulated my questions so as to be able to focus on new and previously unnoticed data (Wallén, 1996). Thus, I tried to ask the interviewees to describe situations and processes with regard to information and goods handling. This also gave me an opportunity to adapt the sub-questions to each individual interviewee, who would thus be answering more nuanced questions (Bryman and Bell, 2007). These more open, semi-structured, but focused questions placed me in a better position to ask deeper questions on the same subject.

During this research project I discovered that I had to create more structured interviews. As I was neither employed by a company, nor involved in collaborative action research, I was usually given a relatively short amount of time to interview my subjects. This was especially the case with the firms that were not the focal actors of the case studies. Therefore, in this study, I tried to read secondary evidence prior to the visit, ask semi-structured, focused, but open questions during the interview, and collect as much secondary evidence as possible. In addition, my intention was to collect data from several organisations in the network surrounding the focal actors in both case studies, in a fashion that could be identified as a snowballing interview strategy. This strategy involved framing interview questions and discussion topics in a process that led to observations which generated new questions on, and dimensions of, the subject, and on which further interviews could be based (Dubois and Gadde, 2002).

Distributed among two cases, Table 3.1 illustrates the categories of interviewed organisations, positions of the interviewees, type of data collected about the firms and their networks, and how data collection was conducted. In total, I conducted 35 interviews with 20 organisations from 2009 to 2014. Of these 35 interviews, 30, which took place within 16 organisations and 37 persons, are included in the chapters 4 and 6 that deal with empirical findings as I decided to focus on the PC industry during the research process. Each interview lasted approximately one to three hours, with the shortest interview lasting 30 minutes and the longest three hours. In addition, in autumn of 2012, I attended a four-hour seminar on recycling and classification technology, recycling regulations, and legislation of hazardous material arranged by Stena Recycling. Speakers and lecturers at this seminar were from recycling firms and public regulatory bodies.

	Organisation category	Organisation	Position(s) of interviewee(s)	Data collection		
				Interview	*Secondary data*	*Observation*
Case study from the disposer's perspective	PC manufacturer	Dell	Sales Manager, Environmental Manager	Personal, telephone	X	
	LSP[29]	Schenker	Sales Manager	Personal	X	X
	Recycler	Renova	Managing Director, Operations Manager	Personal		X
	Distributor	Infocare	Service Manager, Repair Service Manager, Sales Manager, Technician	Personal	X	X
	LSP	IT Logistic	Managing Director, Logistics Manager, 2 Drivers	Personal	X	X
	Refurbisher	Igus Data	Managing Director	Personal	X	X
	Supplier of testing software for used IT equipment	Blancco	Managing Director	Telephone	X	
	Distributor	ReuseIT	Sales Manager	Personal	X	
	Disposer	Region Västra Götaland	Exchange Coordinator/IT Strategist, IT responsible employee, IT Technician	Personal	X	X
	Collector	SITA	Sales Manager and Transport Manager	Personal	X	X
Case study from the reprocessor's perspective	Distributor, Refurbisher	Atea Logistics	Logistics Coordinator, Operations Manager, Recycling and Logistics Manager, Implementation Manager, Configuration Manager, Sales Manager, Service Manager, Technician, Managing Director	Personal, telephone	X	X
	LSP	Schenker	Service Manager, Logistics Coordinator	Personal	X	X
	LSP, Refurbisher	Jemacon Logistics	Logistics Coordinator and Production Manager	Personal	X	
	Collector	Eurovironment	Managing Director	Personal	X	X
	Broker, Refurbisher	Inrego	Quality Manager	Personal	X	X
	Broker, Refurbisher	Once Again	Managing Director	Personal	X	
	Dismantler, Recycler	Sims Recycling	Sales Manager	Personal	X	
	Recycler, Smelter	Boliden Rönnskär	Purchasing Manager	Personal	X	X

Table 3.1 Overview of data sources.

[29] Logistics Service Provider.

In most cases I booked the interviews by phone so that the interviewees could become familiar with the issues I intended to cover before the interview took place. The interviews usually began with a presentation of the project and my research area. During the interviews, the informants were asked to describe processes and physical and information flows with regard to their partners on the supply and demand sides. Issues discussed also concerned cooperation between logistics service providers and consignors and consignees. I taped half of the interviews, and took notes during the other half since some of the interviewees did not want to have their statements and answers recorded on tape. As soon as the interviews had been transcribed, I sent the transcripts to the interviewees and corrected the material in line with their comments.

3.3 Evaluation of the research quality

In order to evaluate the quality of research influenced by a qualitative methodology, Lincoln and Guba (1985) proposed a consideration of the concept of trustworthiness. The main issue in evaluating the trustworthiness of a study is how the researcher can convince *"his or her own audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of"* (p. 290).

Several researchers in the Industrial Network Approach tradition have assessed the quality of their work by applying the concept of trustworthiness (e.g., Holmen, 2001; Hulthén, 2002; von Corswant, 2003; Skarp, 2006; Lind, 2006). These studies have used four criteria proposed by Lincoln and Guba (1985) in order to evaluate the trustworthiness of research: credibility, transferability, dependability, and confirmability. All four of these criteria are described in greater detail below, as they relate to this thesis. Credibility will be discussed first, as it is considered the most significant criterion for the trustworthiness of a study.

3.3.1 Credibility

There are seven processes that can *"make it more likely that credible findings and interpretations will be produced"* (Lincoln and Guba, 1985, p. 301). These activities include prolonged engagement, persistent observation, triangulation, peer debriefing, negative case analysis, referential adequacy, and member checks. Negative case analysis, which is associated with the testing of hypotheses, is not elaborated upon here, as the aim and the abductive nature of this research is not to revise or propose hypotheses. Therefore, all of these sub-criteria, except for negative case analysis, are discussed in relation to the research process followed in this thesis.

Prolonged engagement addresses the sufficiency of time spent in the empirical inquiry so that a broad understanding of the phenomenon in focus can be achieved (Lincoln and Guba, 1985). As I used a network perspective on the phenomenon as a focus for the study, I did not consider it to be a primary goal to spend a great deal of time on studying single companies, (that is, the focal actors of both case studies). I tried to understand how various other firms around the focal actors cooperate to coordinate activities and combine resources. This meant that a connection to a given actor was not the primary objective. Although data collection for each of the case studies was separate, it was more or less continuous from the perspective of the phenomenon in focus. In addition, the analysis of data and the development of the framework were carried out continuously.

Persistent observation refers to gaining a sufficient depth of the context investigated through identification of the most relevant aspects of the phenomenon studied. The interviews with various firms, which perform distinctive activities and resource-combining procedures in product recovery, were based on the conceptually rich framework. This enhanced my understanding of the phenomenon because it gave me the opportunity to receive a deep understanding of the context of product recovery. I identified the concepts of transvection and sorting as central in the early phase of the research process, as they could be continuously observed directly from the empirical findings during the entire data collection process. This was also the case with the 4R model and resource adaptations or tensions that could be spotted in the field. This was done in both case studies. With regard to the actor layer of the Industrial Network Approach, it was important to frame the empirical findings through theoretical concepts that I acquired towards the final stage of the research process. Thus, it is central to note that the analytical tools had an impact on how I viewed the empirical world with regard to transvections, the 4R model, and the analytical tools for the analysis of actors.

Triangulation is usually suggested as a technique for cross-checking data in order to enhance the credibility of a study. For example, trustworthiness of empirical findings may be secured by combining quantitative and qualitative methods (McKercher, 2000). Even though I cross-checked some information given to me by various actors in the network for the sake of logical coherence (Meredith, 1998), the primary aim of data collection from multiple sources in this study was to obtain a broader and deeper understanding of the phenomenon, in agreement with the abductive approach (Dubois and Gadde, 2002) adopted in this study. Thus, in order to compensate for a lack of primary data from some firms, I used data from the interviews with their partners, as well as articles, websites, and other kinds of secondary data.

Peer debriefing is defined by Lincoln and Guba (1985, p. 308) as a *"process of exposing oneself to a disinterested peer in a manner paralleling an analytical session and for the purpose of exploring aspects of the inquiry that might otherwise remain only implicit within the inquirer's mind"*. There was no formally appointed peer during the course of this study. Nevertheless, parts of the analytical framework and empirical findings have been presented at internal seminars at Chalmers, as well as PhD courses, workshops (Nordic Workshops on Inter-organisational Research in 2009 and 2012) and conferences (the Industrial Marketing and Purchasing Group's conferences in 2010 and 2012) in order to provide an external control for the inquiry process. At the Nordic Logistics Research Network's (NOFOMA's) conference in 2013, an article by Insanic and Gadde (2014), which was later published in the International Journal of Physical Distribution and Logistics Management, received the Best Paper award. During the publication procedure, I received many valuable comments from the reviewers. This process also inspired the development of the case studies and the frame of reference.

Referential adequacy refers to keeping collected data as "raw" as possible so that readers can draw their own conclusions. The empirical enquiry within this thesis can be interpreted and analysed in various ways, since I tried to avoid using theoretical concepts and analytical tools associated with different layers of the Industrial Network Approach, for example, in my case descriptions. On the other hand, as all data collection is influenced by the researcher's theoretical background, I cannot claim that the information presented in the chapters on empirical findings can be regarded as the absolute and objective truth. In addition, I selected and analysed the data several times before completing the final version of my case description (Dubois and Gadde, 2002).

Member checks is an activity that contributes to the establishment of credibility. It usually means that the collected empirical material is validated by the respondents (that is, the interviewees). In this study, the interview transcriptions were sent to informants; some chose to make comments on the written material, while others did not, and I revised the material in accordance with the interviewees' feedback. In order to ensure that the perspective of the informants was accurately portrayed, follow-up interviews, telephone conservations, secondary data, and written correspondence were used.

3.3.2 Transferability, dependability and confirmability

Transferability signifies the extent to which actors can apply the empirical findings and concepts to contexts other than those within which the findings were originally developed (Lincoln and Guba, 1985). This concept parallels theoretic generalizability, or what Yin (2003) terms "analytical generalisation", which is the ability and potential to apply theory based on a certain case study to other contexts. In order to establish transferability of the thesis, I believe I have provided a "thick description" that will enable those who are "*interested in making a transfer to reach a conclusion about whether transfer can be contemplated as a possibility*" (Lincoln and Guba, 1985, p. 316). Although this thesis is strongly influenced by the PC industry, I do not consider its conclusions to be limited to the context of product recovery arrangement in this network. With respect to the theoretical framework, one of the theoretical contributions of this thesis refers to connecting the concept of transvection to the product recovery structures. Another theoretical contribution relates to the analytical framework, which integrates all three layers of the Industrial Network Approach for the investigation of product recovery. From an analytical perspective, in addition to other product recovery networks, I believe that this framework can also be modified to analyse other types of business networks, since most of the analytical tools stem from literature on forward physical flows.

Dependability, which relates to *"examining the process of inquiry"* (ibid., p. 318), has hopefully been attained, as I have tried to describe the theoretical and empirical development of the research process in sections 3.1 and 3.2. The reader has been provided with an illustration of issues that arose, and the ways in which these were handled, on a fairly detailed level. I outlined, as fully as I could, the progression of work within this thesis and how the approach to systematic combining inspired continuous interplay between the theoretical framework and the empirical world.

Confirmability concerns an evaluation of the extent of consistency of the applied concepts, findings and data (Lincoln and Guba, 1985). My belief is that this thesis displays coherence between different parts and chapters, as the empirical findings and analytical tools and concepts have been matched. Indeed, I believe that there is consistency in the study, as I tried to select concepts and data for this purpose in line with the spirit of systematic combining (Dubois and Gadde, 2002).

In summary, this chapter contains a rationale on why the abductive qualitative case study approach was chosen, and how this approach has been applied in my research. To conclude, I hope that the combination of collected data, data collection methods, analytical frameworks, and conclusions in this study are found to be inter-subjectively reasonable and trustworthy to other people in academia and practice.

4 EMPIRICAL FINDINGS ATEA

This case description depicts how a large intermediary dealing with IT equipment, Atea Group, takes an active role in managing the goods that are disposed of by firms and organisations in the private and public sector. Atea Group's internal logistics division and coordinator of forward and reverse distribution activities, Atea Logistics, is elucidated, with an emphasis on the product recovery services that it offers to disposing organisations. In addition, in this chapter, Atea Logistics and its collaborators involved in logistics, product classification, recycling, refurbishing, and distribution of disposed-of and reprocessed objects to new end users and manufacturers of the raw materials are described.

4.1 Introduction

As a consequence of the adoption of regulations concerning the reduction of electronic and electric waste being shipped to disposal sites, several European countries introduced logistics systems for recycling of products stemming from the electronics industry in the 1990s and 2000s. The aim of these regulations, which are compiled in the Waste Electrical and Electronic Equipment (WEEE) Directive, is to support effective organisation of the logistics management of growing physical flows of electronic waste. The directive contains guidelines for the classification of products, and the collection rates in terms of kilograms per inhabitant and year. For instance, the Swedish version of the WEEE directive implies a collection rate of 16–17 kilograms per capita and year, stating that at least 80 per cent of all the waste should be collected and recycled, and not sent to a landfill. Besides following the WEEE Directive, reprocessing companies have to obey the EU rules that cover the handling of hazardous and radioactive waste, such as PCB, cadmium, mercury, and lead. Sweden has frequently been one of the first nations in Europe and throughout the world to diminish, and later to completely prohibit, the use of these raw materials before such legislation was carried into effect at the EU level.

In Sweden, implementation of the WEEE Directive and other directives concerning waste is administered by The Swedish Environmental Protection Agency. Each time a new set of modified rules is introduced, it is distributed from the EU level via the Ministry of Environment and the Environmental Protection Agency to municipalities that enforce the rules through inspections, and The Swedish Recycling Industries' Association. The Swedish Recycling Industries' Association is a group of companies that perform collection and recycling activities, who have organised themselves in order to strengthen their position and influence with regard to the present and future legislation. The creation of The Swedish Recycling Industries' Association has led to the development of a platform from which information sharing and interaction on issues concerning the rules for waste classification between the regulators and the industry can take place. The path through which the individual recycling firms can affect the rules and regulations before they come into force, by providing feedback, and correction proposals, goes from the recyclers to the authorities at the EU level. All amendments with regard to the rules that are still in the development phase are carried out by referrals to The Swedish Recycling Industries' Association and its European equivalent, the European Electronics Recycling Association.

The WEEE Directive was created in order to first and foremost control recycling practice. Therefore, it is primarily the recyclers that have to act in accordance with the rules of the Directive. The Swedish recyclers provide reports on their costs and practices to the authorities, and the actors, such as producers, who are financially responsible for the waste management of the disposed electronic goods. These actors indirectly finance the operations of the overall logistics system for recycling through the logistics coordinator, El-kretsen, a consortium of the firms involved in the production and distribution of electronic and electrical products. El-kretsen assigns the volume of electronic scrap to each recycler in Sweden. The consortium's main responsibility concerns the collection of used products from the households.

With regard to the electronic waste from organisations, each organisational disposer is individually accountable for having a suitable supplier of logistics and recycling services. This means that each disposer needs to have a business partner that is knowledgeable in efficient handling of these kinds of goods. This business partner has to comply with the regulations implemented by The Swedish Environmental Protection Agency. The Swedish Environmental Protection Agency influences the structure of the collection and recycling system through their regulations.

The overall network for product recovery includes a number of organisations that perform a set of processes. The product recovery firms place containers at the sites of various businesses and public institutions, which they pick up when fully loaded and distribute to strategically located transhipment terminals. In these distribution centres, miscellaneous electronic and electrical waste, as well as other scrap, is consolidated from many other organisations and households to be classified in accordance with the requirements of the smelters or the remanufacturers. Recyclers charge the disposers for their logistics and pre-treatment services. The state of the raw materials, or in other words, the disassembly difficulties determine whether the recyclers buy the material or get it for free. The output of recyclers is used to produce purified raw materials. Remanufacturers restore the original functionality of products and distribute them to secondary end users either directly or through intermediaries.

The development of the logistics system for recycling was one of the major factors that made the focal actor in this case, Atea Logistics, enter this industry in 1998. At present, Atea Logistics manages and coordinates reverse physical distribution from disposers to the facilities for recycling and other reprocessing options. The role of Atea Logistics within Atea

Group, and in relation to disposers, logistics service providers, refurbishers, recyclers, intermediaries, and secondary end users is presented in the next part of this chapter.

4.2 Atea Group

The Atea Group is one of the major distributors of IT-related products and services in several Northern European countries, such as Denmark, Estonia, Finland, Lithuania, Latvia, Norway, and Sweden. With the local customer base and presence in 82 cities in the Nordic and Baltic region, Atea Group is one of the largest providers of distribution and sales services for new IT products. Atea Group had revenues of roughly NOK 22 billion in 2013. Approximately 6,100 persons are employed by the Group in the Nordic region.

Atea Group delivers IT-related products from the largest manufacturers, and is a specialised supplier of the services that require extensive knowledge of the IT infrastructure. The offerings that are associated with the IT infrastructure include a set of combined product and service arrangements. By collaborating with its internal logistics service provider, Original Equipment Manufacturers, and other actors in the electronics industry, Atea Group handles the physical distribution of PCs (laptops and desktops), servers, mobile phones, printers, monitors, and other electronic and/or electric products.

4.3 Atea Logistics

Atea Logistics, which is Atea Group's internal logistics department with a high degree of independence within Atea Group, is in charge of the coordination of forward and reverse physical distribution, and logistics operations. Apart from controlling and running its own logistics processes, Atea Logistics organises physical distribution in cooperation with firms that specialise in logistics and transportation.

One type of service that Atea Logistics provides is regional and local inventory holding of spare parts. By doing this, the end users may be supplied by these products on very short notice. In order to maintain availability of parts and modules at a high customer service level, Atea Logistics keeps a network of inventories throughout Sweden and the rest of the Nordic countries, as well as all of the Baltic countries.

A key element in the achievement of efficiency in distribution activities is the long-term relationships and partnerships that Atea Logistics has developed with the vendors of logistics and transportation services, sales representatives, and Original Equipment Manufacturers. Close dialogue and collaboration between the Nordic and Baltic sales companies of Atea Group, as well as Atea Logistics, enables the creation and design of assortments of customer offerings. Another benefit of this cooperation between the sales companies and Atea Logistics is that sales companies market the services of Atea Logistics, such as warehousing, transportation, and materials handling of electronic and electric waste, and used IT products, which can be resold to secondary end users. Hence, the sales companies are always involved in all communication between the disposers and Atea Logistics. The organisational structure of Atea Group therefore facilitates a closer relationship between the sales companies and Atea Logistics than between the disposers themselves and Atea Logistics.

Nevertheless, there are other aspects of the relationship between Atea Logistics and the sales companies of Atea Group, alongside those of a collaborative nature. Owing to their independence and extensive autonomy, the sales companies are permitted to purchase the physical distribution services from other competing actors. This purchasing strategy, which is labelled ‘the country is king’ inside of Atea Group, means that any sales company can choose to buy products and services from suppliers that have equivalent competencies to those possessed by Atea Logistics. Whether the external supplier of a sales company within Atea Group is an intermediary or a producer of electronics is of minor importance, as long as the alternative vendor is able to provide similar offerings.

Such an arrangement has its advantages and drawbacks, according to the managers at Atea Logistics. The competitive policy facilitates a pressure on the costs among competitors, which leads to a general and continuous reduction of prices for the end users. In an indirect fashion, this policy benefits the sales companies and the whole Atea Group, as the other firms that specialise in logistics coordination cannot charge the sales companies more than Atea Logistics does. In addition, for the purpose of minimising expenses, Atea Logistics constantly tries to improve its own processes and keep up with the services of other competing companies in the industry through application of this purchasing strategy. This enables Atea Logistics to maintain its position as the chief supplier to the sales companies of services involved in logistics coordination.

Moreover, many firms who are providers of comparable services to the end users are collaborators of Atea Logistics. These partners are also free to select Atea Logistics as their own supplier of the physical distribution services. Thus, employees from competing and cooperating firms, such as Original Equipment Manufacturers and the staff of the sales companies within Atea Group, are sometimes working out solutions that combine forward and reverse logistics processes. This is done in order to manage organisation of the physical flows of electronic waste as smoothly as possible, together with the end users.

Contrary to this situation, the traditional intermediaries of electronic and electrical products have been largely bypassed with regard to the transactions and sales of new hardware and software to the organisational end users. Hence, for example, PC manufacturers have developed business relationships with the end users in which these actors agree upon the specifications of products. Therefore, Atea Logistics sells physical distribution services either to the manufacturers or to the end users, whereas the products are part of the sales agreement of the direct relationship involving manufacturers and end users.

Atea Logistics does not acquire any financial gains from the sales of the products, and merely makes a profit on the sales of the logistics services; this trend has led to a decline in overall returns. This loss of product-related profits has led to a reorientation of the strategic emphasis of Atea Logistics, since the company has become a more pure supplier of services that are associated with the organising of logistics operations. Three following sections will describe the coordinating role of Atea Logistics, the activities performed by the disposers, and the product recovery services provided by Atea Logistics.

4.3.1 The role of Atea Logistics in the organising of product recovery

Since the late 1990s, Atea Logistics has developed business partnerships with a number of actors who have acknowledged capabilities in the management of logistics and reprocessing of used IT equipment and obsolete electronic waste. Therefore, Atea Logistics is now able to offer a set of services that are related to the reverse physical flows, in addition to those that are closely connected to the delivery of new products. Figure 4.1 displays the different actors who perform activities as part of a business network for product recovery, such as the trading of used goods, remanufacturing, and transportation of obsolete items. Furthermore, Figure 4.1 illustrates a set of alternatives with respect to physical flows of products from disposers through the collectors and recyclers to the manufacturers of new raw materials and products (Boliden and Elektrokoppar). This chapter provides a detailed account of these physical flows, the resources employed in the processes for handling these items, and the economic entities involved in organising these networks.

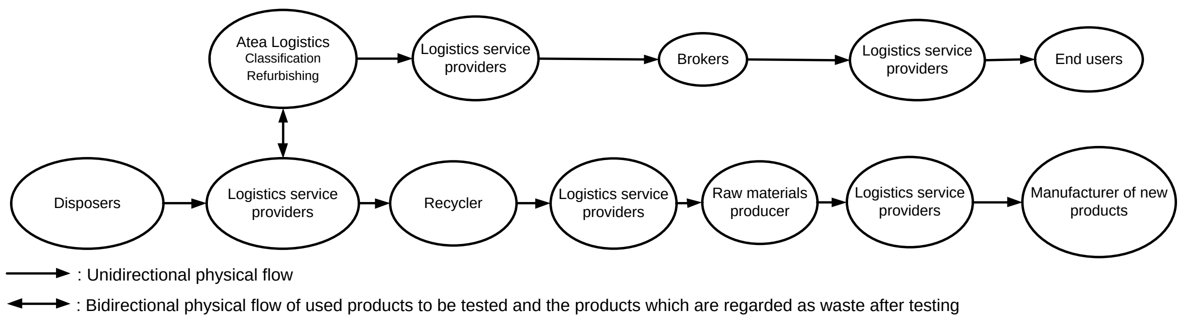


Figure 4.1 Schematic overview of actors that organise processes associated with the physical flows of used products.

The majority of organisations have to dispose of their obsolete and used electronic and electrical artefacts through the systems designed for collection and recycling. A disposing organisation can choose to put the responsibility for these activities on a certain department or division. Very often, it is the purchasing or IT department that is involved in the classification and coordination of materials handling with the reverse logistics service providers and reprocessing companies. However, as the internal departments of an organisation are dedicated to the management of forward physical flows and deliveries of new products, they usually do not have the same access to the expertise, finances, time, or other resources for management of the distribution activities involved in the reverse physical movement of products after their usage has been fulfilled.

With the intention of solving the problem of increased administrative burden on behalf of the disposing firms, and for the sake of lean handling of used products, Atea Logistics has designed a system in Sweden. This system includes uniform pricing for a number of product recovery service packages. The uniform pricing arrangement includes a fixed price for each standardised bundle of services, no matter where in Sweden the order for a particular service bundle is placed. Before implementing the uniform pricing of disposed products, Atea Logistics accounted for all the reprocessing and logistics activities that the items went through, and then sent the data of all these costs to the disposers. This meant that the disposing organisations did not acquire knowledge of the expenses for product recovery activities until all the used products were tested, and consequently either shipped to new end users or industrial units for recycling. Then, the disposers would obtain refunds depending on the amount of functional and demanded used products.

Nowadays, in order to avoid this situation of excessive book-keeping and transactional activities for the disposing firms and other organisations, as soon as the uniform and predetermined expenses for the standardised reverse distribution and product refurbishment have been reported, an organisation that sells used IT equipment receives payment for the usable units that are currently in demand. In order to further promote efficient transactions, price stability, and security for the disposers, the manager responsible for the sales and classification of the disposed items creates a price list with the requested properties of products, which is updated on a month-to-month basis.

Some of the largest private and public organisations and institutions have therefore become reliant on the services provided by Atea Logistics and its recycling partners. In addition, apart from the realisation of reduced administration cost via the instalment of uniform pricing, these disposers have become more aware of the possibilities for minimisation of cost, which might be achieved through the synchronised forward physical flows of new articles and reverse materials flows of used products. This synchronisation is mirrored in the fact that a number of divisions or departments in a company, for example, may take advantage of the spatial propinquity of the location of the products that are to be delivered and collected. In their effort to simplify the administrative work associated with the supply of new IT equipment and the gathering of used electronic and electric products, some of these organisations have decreased the quantity of purchasable product alternatives to, for example, a maximum of six.

Furthermore, certain organisations have gone so far in standardisation of the procurement of the IT offerings that they only handle two standards in terms of the hardware. With the intention of achieving these efficiencies, institutions in the public and private sphere are advancing techniques for more structured access to data about the precise location and the number of years in use of their IT products. By doing this, and through information sharing, the disposing organisations enable Atea Logistics to utilise economies of scale in information exchange between and within organisations, classification of goods, and distribution functions such as warehousing with regard to both forward and reverse physical flows.

Since the warranty and/or leasing period, and the related free repair service, is normally three years, some firms that wish to dispose of their products have become aware that there is a set of benefits that are coupled with arranging the pre-planned equipment exchange procedures. However, according to the managers at Atea Logistics, organisation of the physical distribution for the handling of both newly manufactured units and the used products is not as integrated as it could be. This is caused by the fact that the disposers partner up with separate firms, who in their turn are specialised in a limited number of activities with regard to either the forward or reverse flows of materials. Thus, for instance, in case PC assemblers trade directly with the disposing organisations concerning the new equipment, they advise the purchasing party to get in touch with their collaborator, who is in charge of the reverse distribution processes and assets. This in turn implies that if Atea Logistics is not that particular partner, its chance of establishing the business relationship with the disposer, and hence in getting the contract for taking care of the disposal and reverse logistics services, is very low. As a consequence of these circumstances, Atea Logistics is unable to expand its market share in the industry for the provision of disposal, collection, and recycling of second-hand products and electronic waste.

4.3.2 Materials handling of used products by disposing organisations

The organisations that wish to have their used equipment collected and reprocessed have two main options. The first alternative involves a decoupled method of dealing with distribution of the new products, and collection of the used units. In this case, both the order placement for the gathering and the reverse distribution of the second-hand equipment are independent from the order handling and delivery of new articles. The second option includes an integrated approach to the structuring of forward and reverse physical flows of materials, as the used equipment is exchanged for the new goods in a regular fashion with a fixed number of years between each replacement. This regular replacement programme involves synchronising the gathering of the products that are about to be disposed of, and setting up new products at the workplaces.

In case the order for the collection of the second-hand units and the provision of new offerings are handled separately, the third party logistics provider hired by Atea Logistics transfers the empty load carrier(s) to the site of the disposing organisation. Upon delivery of a load carrier, the disposers fill up them with the used IT equipment. Atea Logistics owns a limited quantity of load carriers (roughly 1,000 units), which have to be sent back to Atea Logistics in order for them to be utilised in other collection procedures. The firms that order the pickup service of used products are permitted to keep a load carrier for a maximum period of two weeks. Otherwise, if the disposers are not ready to return the load carriers, they are charged with a fee for not shipping the load carrier on time to Atea Logistics. This holds for all of the standardised service packages except for those in which Atea Logistics and its partners conduct combined replacement of the used IT products with the new ones. In order to reduce the occurrence of the late deliveries of load carriers to their facilities, Atea Logistics has devised a system that generates reminders for the disposing organisations, who are then retold to place an order for collection of the goods in a maximum of two to three weekdays.

In any case, the most common reason for the delays in filling the load carriers, and their successive return to Atea Logistics, is the miscalculation of the value and characteristics of the items that are in possession of the organisation that wishes to discard its second-hand equipment. This is why developed cooperation and far-reaching exchanges of information between the parties that manage and handle processes associated with the reverse and forward physical distribution makes it possible for Atea Logistics to deliver a list of articles that should be shipped to Atea Logistics' inspection facility. The information on the checklist is utilised to assist the disposers in the appropriate filling of the cages or boxes, depending on the service package selected. The product and end user-specific data on the list may have been saved during the delivery of the articles as new. Atea Logistics is enhancing and developing this technology in order to improve the expediency of the disposers in the handling of the used items and electric and electronic waste. Through this kind of information system for the tracking and tracing of the goods, it is possible to increase the convenience of management of the used products for the disposers, as they will be given the precise data on the placement and state of the IT equipment.

Moreover, the sales companies within Atea Group are making efforts to teach the disposing organisations how to choose and adapt themselves towards distinctive reverse distribution service packages. The intention of these measures is to minimise current and potential disturbances in the processes of classification, quality control, and remanufacturing at the sites where these activities are performed. The disposers are also given written instructions on how to deal with the units they wish to discard. Examples of this kind of advice include the following guidelines:

- For the sake of avoiding damage during collection and transport, the heavier units are to be put on the shelves that are close to the bottom of the load carrier, while the lighter products should be placed at the top of the cages/boxes. This is to be done in order to diminish the risk that the load carriers are tipped over in trucks or warehouses.

- The disposing organisations and the firms that carry out the collection of used equipment are provided with the directive to utilise various types of packaging so as to reduce the risk of transport damages due to inappropriate immobilisation of the equipment. For example, the personnel handling TFT[30] monitors are taught to place plastic bubble wrap on the screens, which are especially sensitive to shocks and pressure.
- To minimise the possibility of entanglement of mice, electric adaptors, keyboards, cables, and cords, these objects are supposed to be put into separate, smaller containers, which in turn are to be placed inside of the load carriers belonging to separate bundles of standardised services for the handling of used IT equipment.
- Cages or boxes containing the used products should be located at or close to wide exits, which have the lowest thresholds possible. The disposing organisation is advised to provide the driver with a manual pallet truck that should be prepared so that the collection of the load carriers is as easy as possible.

In an attempt to lower the number of misunderstandings, Atea Logistics is trying to equip the disposers with manuals on how to classify the products as soon as the order has been placed for a certain service package aimed at the handling of second-hand products, and electronic and electrical waste. As 30 to 50 per cent of the products are unsuitable for reconditioning, the purpose of the classification principles is to direct the units to the facilities that specialise in alternative product recovery options. In other words, the products that do not have any value in the second-hand market should not be transported to the industrial units for refurbishing, and then shipped to a facility for recycling.

This reduction of excessive transportations, and the avoidance of as many detours as possible, is an issue that is dealt with via continuous adjustments of the item classifications between the firms that are responsible for collection and primary sorting, and the companies that work with the alternative product recovery options. In 2011, Eurovironment (an expert in the management of reverse logistics processes) and Atea Logistics were developing guidelines for a more detailed classification and registration, which should take place at the warehouse of Eurovironment in Enköping, with the intention of reducing the number of detours and thus tonne kilometres. The balancing of supply and demand therefore involves the generation of scale efficiency and proper classification of the articles by the collecting company with respect to the changes in demanded product specifications by the secondary end users.

4.3.3 The assortment of product recovery services at Atea Logistics

Atea Logistics, in collaboration with its partners, has developed an assortment of four standardised bundles of services referred to as LOOP services, or LOOPs. Although these arrangements are standardised, they may be adapted to specific customer requirements. In

[30] Thin Film Transistor.

fact, Atea Logistics has standardised two more sets of activities into LOOPs, even though they are not marketed officially on the company's webpage. These additional LOOPs are combinations of the four standardised ones. Table 4.1 displays the schematic summary of the content of the LOOPs.

When a disposer selects a LOOP, issues such as product specifications, quantities, delivery/collection dates, and the sensitivity of the information on the hard drives have to be taken into consideration. Many companies regularly think of inventory holding costs as low in comparison to the costs of materials handling and classification of the units at the end of their useful life. In LOOP 1, LOOP 2, and LOOP 3, the physical flows of the new and used products are decoupled, whereas LOOP 4 includes a structure that entails a combined approach to the forward and reverse distribution of goods. More precisely, LOOP 1, LOOP 2, and LOOP 3 do not normally involve any delivery of new products, while LOOP 4 is an arrangement for integrated delivery of new products and collection of used units.

The shipment of new products and the collection and transportation of used equipment in LOOP 4 is performed with the assistance of the load carriers, which are maximally filled during the forward and reverse physical flows. In addition, the load carriers in LOOP 4 are equipped with wheels that enable an ergonomic materials handling process. LOOP 1, LOOP 2, and LOOP 3 include the cages and boxes, which are delivered empty by the logistics service provider, Schenker, to the disposers; the used products and/or obsolete items are then placed inside these load carriers, which are then transported to various destinations and companies.

The content of LOOP services	LOOP 1	LOOP 2	LOOP 3	LOOP 4
Collection Collection and transfer of the articles from the disposer's site.	X	X	X	X
Environmental handling Optimised environmental handling of equipment – recycling of 99.7 per cent and correct disposal of 0.3 per cent.	X	X	X	X
Quality control Quality control according to ISO14001 and ISO9001 standards.	X	X	X	X
Inspection and classification Separation of scrap from functional units.		X	X	X
Asset information/reporting Asset reporting on all equipment, including volume and weight for scrap and serial no's, inventory no's, etc.		X	X	X
Information security/data erasure Erasing all digital information from equipment using Blancco certified software or degaussing using Ibas (erases media using an extremely powerful electromagnet).		X	X	X
Reconditioning Removal of all corporate identification and labels not related to the equipment itself. Customised production processes are used to remove visible information, depending on the type of equipment.		X	X	X
Steel cage transport Transport in special steel cages. Maximum weight: 500 kg.	X	X		
Steel box/container for secure transport Transport in specially designed steel boxes for secure delivery. The boxes are locked for the entire journey so the contents cannot be identified.			X	X
Handling in a high-security warehouse The recycling centre offers high-security warehouse facilities.			X	X
Handling by authorised employees Equipment is handled by authorised personnel only.			X	X
Purchase of operating units/reimbursements Administrating and purchasing functional units that still have a market value. The customer receives reimbursement when the equipment has been resold.		X	X	X
Synchronised delivery and return Returning used IT equipment in the same carrier that delivered the hardware, including unwrapping of all new hardware.				X

Table 4.1 Summary of the LOOP services (X indicates the type of service included).

As an outcome of a process routinising programme at Atea Group, Atea Logistics created process maps for the most frequently performed sets of functions. The routinising of processes was an attempt to avoid 'reinventing the wheel'; that is, to circumvent the creation and planning of an identical or extremely similar stream of activities that was already being carried out for another or the same customer/disposer. The corporate policy for process standardisation led to the establishment of an information system that stores process maps and manuals for each conducted version of a LOOP service. Hence, every variant of a LOOP service is assigned an article number, via which it is possible to retrieve the solution, and even adapt it to the specific or altered requirements of various disposers. The adjustments are accomplished by adding new sub-processes or removing existing but unnecessary procedures. Although Atea Logistics markets and sells the LOOPs, it collaborates on technological innovation of the LOOP services with other public and private entities, such as disposers, reprocessing firms, and providers of logistics services associated with the reverse physical flows.

As seen in Table 4.1, the LOOP services are characterised by differences in the purpose and content, which is related to the distinctiveness of routines, assets, and actors that are employed within each LOOP service. LOOP 1 is chiefly applied in case the disposer has products that lack any commercial value in their present state, and that do not have any secret data stored on their hard drives. In case the disposer is uncertain about the functionality and product properties, and if the personnel are certain that the hard drive in the product does not contain any sensitive information, LOOP 2 is applicable. Irrespective of the product specifications or functionality, if the information stored in the product (for example, personal data) is not allowed to leak out to a third party LOOP 3 is an appropriate alternative for the disposer. This is why the open cage that is employed in LOOP 1 and LOOP 2 is replaced with a closed and locked cage in LOOP 3. The disposer keeps the steel box for 10 days instead of five. A rolling steel cabinet with a padlock that is safe from an informational point of view is utilised in LOOP 4, when the new, unwrapped products are transported to the disposer, at the same time as the used units are placed in the load carrier that is picked up and transferred to the site for quality control and remanufacturing. For information security reasons, in LOOP 3 and LOOP 4 only authorised staff deal with the products in a dedicated area of the reconditioning facility.

The unloading of new PCs from the rolling steel cabinets, and the filling of the load carriers with the used products, may be carried out by the third party logistics provider – that is, Jemacon Logistics – or the disposers themselves. This kind of integrated delivery of new units, and the gathering of the second-hand products, implies an enhanced utilisation of space in trucks in both directions. This synchronised tactic of arranging forward and reverse physical flows leads to a general reduction of the tonne kilometres, as there is no need to handle backhaul management for the vehicles.

The characteristics of the particular load carriers are tightly coupled with the features and content of LOOPs. This means that apart from the distinctions in the disposers' requirements and processes, each LOOP is connected to a special sort of load carrier. Thus, for instance, the closed cabinet in LOOP 3 fits 50 laptop or 25 desktop units, at the same time as LOOP 4 is coupled with a rolling load carrier into which 30 laptops or 16 desktops can be placed. In other words, each LOOP implies the usage of an exclusive kind of a load carrier, as each set of processes belonging to a certain LOOP has to be adjusted to a number of issues, which include the product characteristics, the sensitivity of data inside the products, and the weight, volume, and number of all units about to be collected.

The properties of the specialised load carriers and their relation to the LOOP services is portrayed in Table 4.2. The major distinction regarding capacity in terms of the quantity of products inside the load carriers in LOOPs is related to the prevention of information leaking out to actors who should not have access to the protected data. As a consequence of the differences in requirements for data safety, and the value of the products, the closed and locked steel cabinets in LOOP 3 and LOOP 4 can fit a smalled number of products compared with the cages in LOOP 1 and LOOP 2.

Features of load carriers in the LOOPs	LOOP 1	LOOP 2	LOOP 3	LOOP 4
Size (width x depth x height (cm)	80 x 120 x 180	80 x 120 x 180	120 x 80 x 180	120 x 60 x 195
Maximum capacity (kilos)	500	500	400	350
Capacity – PC Laptop (units)	55	55	50	30
Capacity – PC Desktop (units)	40	40	25	16
Capacity – Server, PC Tower (units)	35	35	22	8
Capacity – TFT Monitor (units)	12	12	24	20
Capacity – Laptop (units)	60	60	60	60

Table 4.2 Features and capacities of the load carriers in various LOOP services.

The load carriers in all LOOPs are designed with the measurements of standardised pallets and vehicles in mind, in addition to considerations regarding the size of the products placed inside the carriers. With an intention of streamlining the handling of products in the offices and workplaces, the rolling steel cabinet in LOOP 4 is adapted to the standardised size of the doors, elevators, houses, and buildings in Sweden. By doing this, the driver is able to execute the collection of second-hand products and the instalment of the new products in an ergonomic manner. Figure 4.2 shows the distinction between the load carriers that are utilised in all the four LOOPs. The first load carrier, on the left on the figure, is a steel cage on a pallet, which is used in LOOP 1 and LOOP 2.

Figure 4.2 Load carriers adapted to different LOOPs.

Each load carrier is labelled with a unique tag that facilitates the recognition of products, and communication and management of the physical flows between the actors by providing the possibility to alter and store data about the location of the product, the dates and points in time for collection and delivery of the articles, and the respective sending and receiving business entities. The tag and the corresponding article and/or order number also serve as a mechanism for the confirmation and update of the state of every single product or cabinet depending on the desired level of detailed description. As the information about incoming goods becomes available prior to the actual delivery when the load carrier or product is scanned, Atea Logistics is able to plan the operations concerning testing and reprocessing inside its facilities.

4.4 The coordination of physical flows in LOOPs

The primary organising task for Atea Logistics involves delivering new equipment to end users, and collecting used goods for quality control, refurbishment or other reprocessing purposes. The used IT equipment is acquired via two main methods. The most frequent and standard means occurs when the organisation that wishes to discard the products gets in touch with Atea Logistics and books a LOOP for collection of the products. The other approach involves integration of the forward physical flows of new products, and the reverse physical flows of used and/or obsolete products.

As mentioned in the previous section, a disposer that places an order for collection of the used IT equipment needs to consider the state of the equipment, the confidentiality of the data inside it, and the potential monetary value of the product in an attempt to make the appropriate choice of LOOP services. The cost of each standardised LOOP includes a uniformly priced service package and a price that is related to the weight of the goods. From the disposer's perspective, the most economic service package is LOOP 1, while LOOP 4 is the most expensive.

When a LOOP is ordered, a booking order is sent to Atea Logistics, which then forwards the order to Eurovironment and Schenker, who contact the disposer for pickup.[31] The practical side of the logistical part of the order is organised by the Transportation Department of Atea Logistics, in cooperation with Eurovironment, Jemacon Logistics, Posten, and Schenker. As stated above, the sales companies of Atea Group act as gatekeepers, since they are in the most direct contact with the disposers. In this role, the sales companies are the organisational units, whose primary job is to deal with the administration of customer orders coming from the disposers, which are then transmitted to the collaborators of Atea Logistics who organise the distribution and remanufacturing or repair of products, parts, and raw materials.

[31] Since 2012, Jemacon Logistics has performed all the activities previously performed by Eurovironment.

With regard to the services associated with reverse logistics, two of the primary responsibilities of the Operations Department at Atea Logistics are implementation of the orders forwarded from the disposing organisation through the sales companies, and the provision of information about the advantages of LOOP services to the employees of the sales companies. The processes are actually executed by the technicians within the Operations Department, who receive the disposer orders in the form of assignments. So far it has not been possible to routinise all the activities, since disposers demand customer-specific adjustments of the LOOPs. This leads to adaptations that require changes in the efforts to coordinate and administrate physical distribution, reprocessing, and transmission of orders between the business partners in the network. The handling of the disposers' orders, product recovery services, reconditioning by Atea Logistics, and distribution of reconditioned products are discussed in the next four sections.

4.4.1 Administration of the disposers' orders

When the order for a LOOP is placed by a disposer to a sales company belonging to Atea Group, it is subsequently forwarded to Atea Logistics. By filling out a form that is coupled with an order number, the disposer is obliged to articulate precise information about the organisation, which includes the pickup location and time. Each order number becomes associated with the article numbers of the products that are to be collected. This structuring of information facilitates coordination of the physical distribution and the creation of reports whose aim is to provide the disposers with data on the types of activities that have been carried out on their equipment. In fact, it is not possible to plan the operations at the Atea Logistics' remanufacturing plant if the order has not been sent in an organised manner in advance of the product's or load carrier's arrival to the facility.

Therefore, in general arrangement of the processes is assisted by the information through which order and article numbers are connected. In other words, several products and their respective article numbers fit an order number. The article number is in its turn composed of a checklist, on which a set of operations in each ordered LOOP is defined and thoroughly described.

Processes for handling used products are therefore activated by unique disposer orders, at least with regard to the address and date. As a result, operations are generally guided by the orders that are composed of article numbers. In turn, each article number contains a checklist with the activity description of a particular LOOP service. Furthermore, the order and article numbers provide the information required for the combined gathering of the used products and the delivery of new IT equipment. This information system enables a visualisation of the operations and related instructions for the technicians at the refurbishing facility of Atea Logistics, who acquire the directives inherent in each article number on the checklists through scanning of the labels. These checklists enable the proper execution of the reverse logistics activities, such as collection of the second-hand equipment.

4.4.2 Overview of the product recovery processes

Each LOOP involves a set of predetermined and routinised activities, which include collection, transportation, classification, consolidation, and reprocessing. The division of labour – that is, the actors and the activities they perform – are depicted in Figure 4.3. Since LOOP 2 and LOOP 3 display a large number of characteristics that are alike with regard to the actors and processes, they are portrayed together in Figure 4.3.

The process of collection of the second-hand IT equipment is administrated by Eurovironment on its own, or together with Schenker. On the other hand, Jemacon Logistics only deals with collection of the items in LOOP 4, at the same time as collection of the second-hand products is coordinated by Eurovironment and Schenker jointly, with Schenker executing the actual physical activities. More precisely, Schenker's job is to collect the boxes or cages, depending on the disposer's LOOP selection, and distribute this load carrier to a hub in possession of Eurovironment. In the following section, each LOOP service is explained with detailed reference to the sub-processes that individual companies perform.

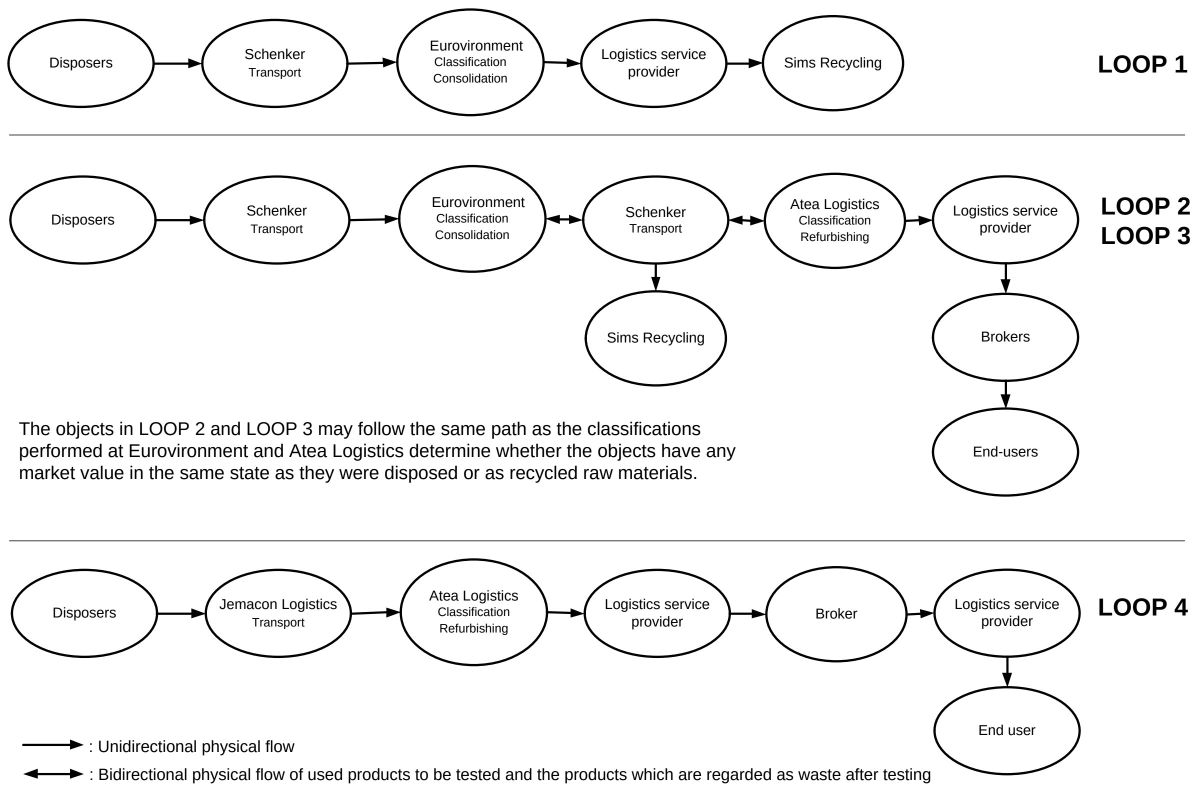


Figure 4.3 Diagram of actors involved in the physical flows related to Atea Logistics' four standardised services (LOOPs) aimed at handling of used products.

When an order for LOOP 1 is placed, Eurovironment administers communication with the disposer regarding the transport of an empty load carrier to the disposer's site. The box on the pallet is to be loaded by the disposers during a period of five weekdays, upon which the load carrier, with a maximum capacity of 60 laptop units and 40 desktops, becomes transferred to a facility where the equipment is classified in accordance with the requirements posed by Sims Recycling Solutions (hereafter Sims Recycling). Sims Recycling, which specialises in the separation and shredding of raw materials from the electrical and electronic waste, defragments the raw materials in order to achieve the level of material purity adjusted to the industrial units of the producers of new raw materials. Therefore, since the units in LOOP 1 are regarded as waste and do not contain any stored information that requires deletion, these items are not distributed for inspection at the Atea Logistics' refurbishing facility in Växjö.

Although there is a certain possibility that a product can take the same route as in LOOP 1, with regard to the actors who handle the materials LOOP 2 contains a number of aspects that make this bundle of services different from LOOP 1. The lack of knowledge with regard to the functionality and commercial value of the disposed-of unit in its current shape opens up several alternative product routes with respect to remanufacturing, besides the one taken in LOOP 1. In addition, the need for the protection of data inside the equipment determines the destination of the product. The classification of the discarded articles at Eurovironment's warehouse is decisive for the choice of direction for a particular product.

The order for pickup of the products in LOOP 2 is transmitted through the sales companies of Atea Group. This order triggers the distribution of empty load carriers to the disposer's site, and their loading and subsequent shipment to the warehouse for classification of the products with respect to distinctive product recovery options and the need for erasure of all disposer-created data. The units that are assessed as being without any monetary value and information are dismantled into parts by considering the raw-material composition of the components. Therefore, such products follow the same routing as those in LOOP 1. The significance of preventing data from leaking out is reflected in the fact that the price of the product itself as it was dispatched by the disposer is unimportant when it comes to handling the units that can be used to store information digitally. These products are transported to Atea Logistics' facility in Växjö, where the data is erased. Here, the items undergo additional quality control checks, whose purpose is to classify the products into those with potential secondary end users, which are sent to the intermediaries of second-hand equipment, and those that should be recycled and transported to the producers of raw materials.

The execution of the disposer order for collection in LOOP 3 starts when Atea Logistics sends a closed and locked cabinet to the site of the disposer. The disposer has five weekdays to finish filling the load carrier before it is collected. As in LOOP 2, the initial product classification is conducted by Eurovironment, whose personnel directs the items to a materials shredding facility by dividing them into a number of material groups, or to Atea Logistics for a detailed assessment of the product specifications. The articles that carry information, or are regarded as having a financial value in their current shape at this point in time, are distributed to Atea Logistics. At Atea Logistics, all data is deleted and all of the product characteristics are thoroughly inspected. Depending on the results of the testing, the items that are functional and worth repairing are transferred to new end users. After the data is erased, the unrestorable articles and goods that do not have the required properties are distributed to Eurovironment for classification into fractions with regard to the internal raw materials content of the used products. Subsequently, the consolidated and separated materials are transported to the premises where they are classified in detail and then shredded into small pieces.

The function of LOOP 4 is to secure remarketing of almost all of the disposed-of products in the same shape as they were purchased in the first place. The synchronisation of forward and reverse physical flows is included in LOOP 4, although the processes that are connected to the forward physical flows may be carried out without any collection of the used equipment, such as in the case new offices being equipped with new PCs. There are a number of alternatives available for this service package available, which are discernible by factors such as the size of the order in terms of the number of units, weight, and volume. An order placed for several thousand PCs by a large company requires more planning, and it is rarely practical or possible to deliver this amount of PCs at the same time, implying that this kind of operation has to be distributed over a longer period of time. On the other hand, a customer (that is, disposer) with a small number of employees can demand a quantity of articles that can be exchanged during a single day, which can be completed at short notice.

When it comes to the execution of LOOP 4, there are two ways to arrange the division of labour between the disposers and the firms responsible for the collection of new equipment. Disposers, or their IT departments, can be responsible for unloading the rolling load carriers, and installing the products, delivered by Jemacon Logistics, within the workplace. As soon as the disposers are finished unloading the new products and filling the load carriers with the used products, Jemacon Logistics picks up the articles. The other possibility refers to letting Jemacon Logistics and Atea Logistics do almost everything with regard to gathering the used products and distributing the new products. In this case, Atea Logistics removes the packaging from the new products, installs the software, and loads the rolling cabinets with the laptops or desktops. Jemacon Logistics transports the load carriers with the new equipment to the end users, collects the used products, and ships these through their hubs or directly to Atea Logistics’ premises in Växjö. In order to optimally utilise the truck capacity in relation to the distance, Jemacon Logistics collects the used products from the disposers in urban areas with small trucks or vans, and transports bigger loads to more distant places with larger trucks. For this reason, Jemacon Logistics controls a number of hubs, which are adjacent to almost all Swedish towns.

According to the managers from Jemacon Logistics and Atea Logistics, LOOP 4 offers relatively superior customer service for the end user/disposer at a low cost. First of all, in case of the full synchronised integration of forward and reverse physical flows, the same truck is completely loaded, without any need for backhaul management. Second, there is no need to transport unnecessary packaging as the unwrapped products are distributed to and from the disposers. Third, the end user/disposer within the company's IT department does not have to bother with removing the packaging surrounding the new equipment, or installing the software in the new units.

To summarise, all LOOPs, with the exception of LOOP 4, involve distribution of products from the disposers to Eurovironment's warehouse. Here, the products are grouped into raw-material fractions, or into items that can be restored in their present state. Regardless of the destination, the classified equipment is kept in storage in anticipation of a full truck load.

In the reverse logistics network for the collection and transport of products to Atea Logistics' premises, the overall period for complete turnover of the inventory is approximately two weeks, implying that the average time for inventory holding of the products before they arrive at Atea Logistics' premises is 14 days. As the quantity of used products is constantly growing, and hence the trucks headed for Atea Logistics' industrial unit are filled quicker, the period of time during which the products are stored is continuously decreasing. The specific processes followed at Atea Logistics' reconditioning facility are explained in the next section.

4.4.3 Processes at Atea Logistics' reconditioning plant

Atea Logistics' reconditioning facility in Växjö processes 200,000 used IT-related products annually. Approximately half of this quantity is laptops, desktops, and associated accessories. At the site, there are several inspection and testing points where decisions regarding the reprocessing alternatives are made.

There are several ways to distinguish the products, parts, and materials from each other. One of these is by the order and article numbers, which are closely connected to each other since the article numbers are included in the order numbers. Each order number may in turn be separated into a set of codes that represent the locations of pallets that contain articles. This administration system provides the possibility for Atea Logistics to track and trace every single product through the pallet position label. Moreover, a supplementary purpose of the system is to consolidate and co-load the reconditioned products that are to be transported to the same geographical location, for example in the case of two buyers that are located close to each other. With regard to operation related to the internal materials handling, the employees of Atea Logistics are able to streamline the routing of trucks, which may pick up adjacent pallets with the demanded goods.

As soon as the used products arrive at the reconditioning premises, the order number of the LOOP is registered and scanned. When the registration is accomplished, the products are inspected and refurbished, or stored and sent to a recycling facility later on. The first method to classify the goods is by the type of the products, which are grouped into desktops, laptops, copiers, printers, scanners, and monitors. Some of the PC accessories, such as keyboards, mice, cables, and electronic waste such as old coffee machines, are usually not recorded in the information system, as they are not of any financial value and do not have any disposer-created data stored. Therefore, once a sufficient volume for efficient transportation is amassed, these items are transported to the facilities for classification by their raw materials composition, and further down the chain to materials shredding and subsequent production of new raw materials.

Laptops and desktops whose specifications are in demand are primarily inspected in terms of the speed of the processor. Thus, if the identified speed does not match the one demanded, the product is recycled after a data erasure procedure involving an electromagnet called Degausser. Once this deletion is complete, these items are classified in accordance with the content of the raw materials inside of them, such as plastics, metals, and glass. These material fractions are then stored until economies in transportation to the industrial units for recycling can be exploited.

Depending on the choice of disposer or manufacturer that leases the product, Blancco or Ibas software is applied to erase the disposer-generated data in the machines, and to identify the features of the products. In case the specialised software[32] is unable to delete the information, Degausser is used to remove all information from the units. The utilisation of Degausser implies a complete erasure of information, as all the data becomes irretrievable.

On the other hand, if the data erasure by the software has been successful, the same software is used to identify the original and defective specifications, such as the memory or processor speed, through a comparison of the properties of the used articles with the established ones stored on the inspection form. The structure of the information in the form is also used to send reports about the operations performed on each unique article through a serial number. Apart from being a facilitator of the information exchange, the inspection protocol provides a possibility to adapt the information in relation to different actors, such as the sales representatives of Atea Logistics and the brokers of the reconditioned products.

The generation of accurate product features by Blancco or Ibas supports the pricing and evaluation of any IT equipment. In practice, the product evaluation is accomplished through connection of the specifications of each unit to a grading system, which is used throughout the reconditioning industry. That is to say, each grade is added as an additional feature of the

[32] Which is certified by the Swedish Defense.

serial number of a particular product. There are four kinds of grades that are translated into distinctive product recovery alternatives:

- Grade A: Used products that are fully functional and in demand.
- Grade B: Fully functional goods with some components that require replacement.
- Grade C: Equipment that needs to be reconditioned to a greater extent than the B-graded units, as when there are several malfunctioning components.
- Grade D: Products that are not marketable since it is not profitable to recondition them, implying that these articles will eventually be recycled.

The technological development of the products is reflected in the continuous changes of the demanded product specifications. This leads to constant alterations in the grading system. The majority of firms in the refurbishing industry are aware and knowledgeable of the precise definitions of the product features related to grades A and B. With respect to grades C and D, there is less agreement on the specifications among the actors in the business, which in turn means that development and modification of these grades requires more negotiation and communication.

Once the product specifications have been generated by means of the specialised software, each unit is given a serial number that is used to assign the product attributes, including the price and grade, to every single article. To be more precise, employees that work with reconditioning conduct a comparison between the features and corresponding values of a particular product in order to price it in accordance with the price list provided by the Sales Manager for the refurbished products. The articles that can be redistributed to new end users are listed in a database/inspection protocol, which is used for the remarketing of products to brokers, and data erasure reports, which are sent to the disposers. The disposers in their turn receive information about the reconditioned products from Atea Logistics, and the number of kilos of the recycled electronic waste from Eurovironment. The material shredding and separation is carried out by Sims Recycling. Around half of the products in LOOP services end up being recycled, and merely 0.3 per cent of the goods are transported to a dump. Hazardous waste in these items is treated by a firm that specialises in handling these types of materials. The other half of the disposed articles is reconditioned.

During the reconditioning procedures, some products may turn out to require replacement parts after the quality control. For this reason, Atea Logistics stores used but functional components, which are removed from the products that were regarded as unprofitable to remanufacture as whole units. As soon as the inspection and other processes at Atea Logistics' premises are finished, the products are transferred to brokers who, among other things, upgrade the equipment by installing new components and software, procured from the distributors of new goods. When the goods are ready to be distributed to the brokers of the second-hand articles, Atea Logistics attempts to achieve a balanced match between the vehicle size and the reconditioning batches.

4.4.4 Distribution of reconditioned products by Atea Logistics

The Sales Manager of the second-hand equipment at Atea Logistics has two objectives, as he tries to guarantee the fixed prices of used products to the disposers and make a profit on the sales of the reconditioned articles to brokers. The brokers, in their turn, facilitate information exchange about the demand to Atea Logistics, which serves as a foundation for the pricing. This information enables Atea Logistics and the sales companies of Atea Group to ensure that a disposer will be able to charge a predetermined price for a used product, up to three months before it is collected.

In contrast to the majority of companies in the product recovery business, Atea Logistics offers fixed prices for the services provided to the disposers and the used products from these firms and public institutions. Other companies that offer product recovery services do not take the risk of a possible loss of profit in case the price of a certain model drops during a single month. Such a drop in the European market may be caused, for example, by the decision of a large German end user/disposer to exchange its assortment of a limited number of product variants. Unlike Atea Logistics, another company dealing with reverse physical flows could therefore have offered a higher price from the start, which would then have to be reduced due to the price fall. All in all, Atea Logistics' competitors offer a more flexible and variable solution in terms of prices and processes, which is frequently perceived as undesirable because of additional uncertainties. These firms reimburse the disposers when all of their costs have been accounted for, and these costs are not certain until each individual product is inspected. Owing to the periods of high price fluctuations, many small firms that are typical of this industry may go bankrupt, since they cannot spread the risks across several departments and units as Atea Logistics does with respect to Atea Group.

One way to solve the problem with this uncertainty is to promote very early order placement for the collection of the used products. For example, if a disposer communicates to Atea Logistics that he or she wishes to get rid of a thousand of laptops, half a year ahead of their collection, the Sales Manager of the second-hand products will be able to offer generally fixed estimated future prices to the disposers. Concurrently, the planning of reverse logistics operations could result in maximal efficiency and effectiveness of the actual activities. This organisation of operations would increase the chance of attaining customers for used articles before these items enter the industrial unit for reconditioning. In 2010, merely 10 per cent of the products were bought prior to them being controlled at Atea Logistics' facility in Växjö.

According to the Sales Manager of refurbished products, the most preferable process configuration for Atea Logistics would combine such organisation of activities, coupled with integration and synchronisation of the forward and reverse physical flows in LOOP 4. Atea Logistics would then be able to equip each new product with a tag containing information about the future disposal, such as the collection address and date. In addition to storing this data in the article numbers, this information would be placed in a database that would transmit automatic reminders to the end users to place the orders for replacement of the equipment. This arrangement would further improve the possibility to sell the units to the brokers prior to their entry onto Atea Logistics' premises, because the quality of the product would be more precisely predetermined than in LOOP 1 or LOOP 2.

A total of 80 per cent of the refurbished products are distributed through five brokers. Atea Logistics has developed close partnerships with two of these brokers. One of the close partners is a firm called Inrego. The rest of the reconditioned units are managed by numerous small to medium-sized companies. There are two main reasons for why Atea Logistics only chooses to sell the refurbished products through these two intermediaries. First, the brokers are skilful and experienced in providing this function to the end users, and Atea Logistics has no desire to manage this service. Second, Atea Logistics does not wish to get involved in a potential conflict with the PC assemblers and the sales companies of Atea Group, which use Atea Logistics to market new products in case an end user procures reconditioned units purely for the sake of replacing the malfunctioning units. More precisely, the suppliers of new and used products are in competition, as end users can make selections between these two alternatives at a specific point in time. This is valid as soon as a buyer has a choice to substitute the erroneous units with new or used products, or when complete replacement of the equipment is postponed. With respect to the competition on the supply or disposal side, the brokers in Sweden who work with Atea Logistics have relationships with the disposing organisations and PC assemblers, who may switch between the suppliers of reverse logistics services.

With regard to the choice of collaborators among the intermediaries, Atea Logistics cooperates only with brokers that abide by corporate social responsibility policies, under which it is not allowed to sell electric and electronic waste to developing countries. Nevertheless, the distributors or end users in developing countries are important business partners for the first-tier brokers that buy palletised, refurbished units from Atea Logistics. These pallets are combined and/or separated with other articles depending on the requirements of the purchasers. Owing to the fact that Atea Logistics does not equip the reconditioned units with mice, keyboards, or software, the brokers in several tiers adapt the refurbished products for the end user through the provision of customised accessories.

The uncertainty in the reconditioning industry is caused by a low level of integration between the disposing organisations and the end users, which is reflected in the fact that it is impossible to guarantee the number and features of products offered to the secondary end users. Enhancements in the management of the physical flows through the reduction of uncertainty would occur if the orders were to use a structured means by which to send information about the products in use to the parties that are collecting, reprocessing, and distributing the articles before they get picked up.

So far, the businesses dealing with the used products have tried to manage the uncertainty via many supplier/customer relationships in order to leverage supply and demand. Atea Logistics has found itself in situations where many brokers require units of similar, and even identical, quantities and qualities. What in fact occurs is that the end user forwards its demand via Atea Logistics' partners, implying that Atea Logistics can exploit the situation of the seller's market.

As a result of the extreme dynamism of the business, credit is very rarely given to any buyers, whether they are intermediaries or end users. The practice of giving credit led to bankruptcy for one of Atea Logistics' brokers, Once Again, when it did not receive payment from one of its customers; this indirectly affected Atea Logistics, which lost a part of its sales of reconditioned products.

The operations of Once Again will be discussed in detail in section 4.7. In section 4.6, the operations of a broker, Inrego, will be presented, while sections 4.8, 4.9, and 4.10 contain information about the logistics service provider, Schenker; the recycler, Sims Recycling; and the manufacturer of raw materials, Boliden Rönnskär. Except for LOOP 4, in which Jemacon Logistics and Atea Logistics manage the collection of used products from disposers, this first step in all LOOPs is managed by Eurovironment. Therefore, the following section introduces this collection coordinator for LOOP 1, LOOP 2, and LOOP 3.

4.5 Eurovironment: a coordinator of reverse physical flows

Eurovironment, based in Kista, Sweden, coordinates deliveries from disposers such as regional governments to the reconditioning and recycling firms. Eurovironment works with three kinds of actors in product recovery configurations: disposers, firms that buy used/reconditioned products, and companies that are responsible for the management of electronic and electric waste in accordance with legislation. The company reached a turnover of 10 million SEK in 2010, and operates in line with the standardised Quality and Environmental Management Systems. For the sake of meeting the increasing demand for Eurovironment's services, the firm has made financial investments into the expansion of its warehouse where, among other things, the product classification is carried out.

With regard to the organisations on the supply and demand side of Eurovironment, their core processes refer to the management of logistics, and classification and subsequent steering of products into appropriate product recovery options. More precisely, together with its business partners, Eurovironment organises collection of used IT equipment, integration and synchronisation of activities related to forward and reverse physical flows, and redistribution of reconditioned units, and electronic and electric waste. Repaired and remanufactured products are marketed to the brokers of second-hand equipment or secondary end users, while the items that are regarded as malfunctioning or not in demand are grouped according to the content of the raw materials, and then transported to recycling firms.

Eurovironment carries out coordination of physical distribution, and classification of products with regard to reconditioning and recycling for Atea Logistics. At a number of points in the logistics network, Eurovironment makes decisions that relate to classification and the determination of product routings into distinctive facilities that are adapted to differentiated product recovery options.

In 2011, Atea Logistics and Eurovironment were planning to create a Nordic logistics network for electronic and electric waste. Since there are great restrictions with regard to the movement of waste across national borders in the European Union and in the Nordic regions, most of the firms in this business are oriented towards national logistics systems for recycling. These structures have led to national sub-optimisations that are not sustainable from either an economic or environmental perspective. In order to improve the economic and environmental aspects of these logistics systems, Eurovironment, Atea Logistics, and other companies in the industry are aiming to influence the regulating body to make changes to the restrictions. Apart from this cooperative project, Atea Logistics has been influential with regard to the development of an information system for the collection and transmission of data about the state of the product throughout the logistics network. One function of this system is to assist various actors in order handling.

4.5.1 Handling of orders from disposers

Each day, the sales representatives of Atea Group receive a certain quantity of orders for the collection of used equipment, which is then sent to Eurovironment through Atea Logistics. When this initial information exchange has been accomplished, every order is attached to a certain order number that facilitates tracking of products, pallets, and other kinds of load carriers. The structure of data in an order number contains information about the ordered LOOP, collection and delivery times, and locations. The order file is sent to Eurovironment, which contacts the disposing organisation to validate the order as well as communicating the order to Schenker for logistics coordination.

Although the exchange of information between Eurovironment and Atea Logistics has been working well, Eurovironment has suffered from some communication difficulties. According to the Managing Director of Eurovironment, there have been delays during pickup of used products owing to the fact that communication is insufficiently organised, and that too many actors administer information. More precisely, when the order for collection is placed by the disposers, the sales companies always forward it to Atea Logistics, which in its turn transmits this data to Eurovironment. Thus, after being managed by four actors, the order information is delivered to Schenker, which executes actual collection from the disposers, instead of this being shared with other actors as soon as a pickup project is booked.

During development of the business relationship between Atea Logistics and Eurovironment, there was a phase in which both organisations experienced complications with regard to the correctness of information. These disturbances led to difficulties in the management and performance of reverse distribution processes. Hence, the central goods department of an organisation could receive empty load carriers, and deliver them to 10 buildings in an office block for loading of electronic waste without reporting this to Eurovironment and Schenker. When the cabinets were ready for pickup, Schenker faced difficulties in localising the used equipment as it expected the goods for collection to be situated at the goods department, rather than being scattered throughout the office block.

With the aim of improving the accuracy of data needed for collection of the used equipment, Eurovironment created a form that is utilised to store data on each disposer for the sake of reusing these data during the collection of electronic and electric waste from a certain disposer at any given time in the future. This information referred to such data classes as the name of managers at the disposing organisations that handled disposal, their contact details, delivery/collection spots/times, the size of the facilities (such as the height and breadth of entrances and rooms), and the opening hours. The development of an organised way to handle information has enabled Eurovironment to acquire more information in general, and more detailed knowledge of the disposers from the logistical point of view, compared to the sales companies within Atea Group or Atea Logistics. Therefore, all of this data, and the particular structure of the information system, facilitate successful organisation of the physical flows.

In their role as intermediaries, Eurovironment and Atea Logistics facilitate coordination of accurate information flow and physical flow between the disposers and the new end users and the recycling companies. The integration of information systems between these firms enables positioning of the products, pallets, and cabinets every time they are scanned, in addition to providing information about their expected arrival and departure from the premises of the disposers, Eurovironment, and Atea Logistics. Furthermore, depending on where a disposer is geographically situated, Eurovironment and Atea Logistics can optimally rearrange distribution processes in order to generate economies of scale with regard to their warehouses and transportation alternatives. For example, instead of always transferring the used equipment from the disposing organisations to Eurovironment, some goods coming directly from several disposers located closer to the facilities of Atea Logistics than to the premises of Eurovironment can be consolidated, and then shipped to Eurovironment for classification.

4.5.2 The processes performed by Eurovironment in LOOPs

With regard to LOOP 1, LOOP 2, and LOOP 3, Eurovironment has the role of a logistics coordinator, and of a firm that manages classification of the IT equipment in relation to alternative reprocessing operations – that is, recycling or reconditioning. In all of these LOOPs, Eurovironment links the communication channels between the disposers, Atea Group, and Schenker in an attempt to organise distribution of empty cabinets to the disposers, and pickup after they are fully loaded. Apart from arranging the physical flows towards Atea Logistics, Eurovironment and Schenker always make an effort to co-load shipments from other senders and receivers in the same geographical areas.

Once the products have been transferred from the disposing organisations to Eurovironment, the physical flow is divided into a stream related to recycling and a stream related to reconditioning. This separation of the physical flow is assisted by a classification manual, which is a subject of continuous negotiation between Atea Logistics and Eurovironment. The general item definitions are included in the contract between the two parties. Nevertheless, the colleagues have to teach newly employed staff to classify the products, parts, and materials in a suitable way because it is not possible to write down all changes to routines and knowledge needed to classify the articles. This holds for ad hoc situations in particular.

Hence, with regard to classification of industrial units for recycling, the products that are neither in-demand nor repairable, and the articles that do not have any disposer-generated data inside, are transported to firms that control the parts in a more thorough way. According to the classification manual established between Atea Logistics and Eurovironment, the products that are working and have a value for new end users in the same shape as they were bought by the disposer are sent via Schenker to the premises for reconditioning by Atea Logistics. Moreover, all the articles with disposer-created data have to be transported to Atea Logistics, where all of this information is removed. In an attempt to increase the loading rate of the trucks, and to generate economic transportation by means of larger vehicles, Eurovironment consolidates the goods over a period of time from a number of disposers, reconditioning firms, and Atea Logistics.

When it comes to classification in relation to recycling, this electronic waste can originate from the disposers in LOOP 1 or from Atea Logistics in the rest of the LOOPs. Thus, when a product has been proven to be without any potential value for new end users, and the process of data erasure has been completed, the item is distributed to Eurovironment. Eurovironment then carries out a classification of parts and items into 12 groups of materials, and therefore 12 distinctive load carriers, which are subsequently co-loaded in load carriers of a higher order, such as large containers.

Recycling specialists screen the characteristics of the 12 material fractions delivered from Eurovironment. This quality control includes shredding of the fractioned waste and separation of the waste into as pure raw materials as possible through an inspection of density, magnetic features, and the content of distinctive material elements. These operations, which are carried out by one of the largest recycling companies, Sims Recycling, are discussed in more detail in section 4.8. The following part of this chapter will discuss the physical flow of the products in LOOP 3 and LOOP 4 that have a market value as intact units, and are therefore reconditioned by Atea Logistics in order to be distributed to an intermediary, Inrego.

4.6 Inrego: a supplier of reconditioned products

Inrego (labelled a broker in Figure 4.1 and 4.3) is involved in the management and actual performance of activities such as reconditioning and distribution of used IT equipment. Inrego's key competence is in providing cost-efficient and socially and environmentally sustainable offerings within the electronics sector. Enhancements of Inrego's capabilities in planning of its distribution processes facilitate continuous reductions in both costs and CO_2 emissions.

Inrego is the largest supplier of these offerings in the Nordic region, and is striving to become one of the leading European actors in the handling of used products. The company is active in organising the general inter-firm structure for the distribution and reprocessing of used products in Europe. Inrego has experienced a great expansion of turnover, as its sales have tripled since its opening year in 1995. At Inrego's premises, 15,000 laptops, desktops, copiers, monitors, and other IT products are handled by 50 people, who recondition the units and sell them to end users and other intermediaries. Inrego has developed relationships with hundreds of firms on its supply and demand side in the United States and all over Europe. All of the brokers and reprocessing partners with whom Inrego works have to follow policies that promote the prevention of electronic and electric waste being exported to developing countries that lack organised logistics systems for recycling of these items.

A customised approach to collection of the used products from disposers involves the contracting of materials handling tasks to a number of third party logistics providers: Posten, Schenker, IT Logistic, and Jemacon Logistics. Each of these firms is specialised in a distinctive range of activities. This differentiated cooperation facilitates effective gathering and transportation of used units from the site of a disposer to the reconditioning plant and Inrego's warehouse in Täby, Sweden.

One service that is increasing in importance is related to the integration and synchronisation of forward and reverse physical flows. Nowadays, this arrangement, which involves the regular replacement of products on a three-year basis, represents 50 per cent of Inrego's turnover. Similarly to Atea Logistics, Inrego offers a fixed price for the product a month before the collection, under the condition that the disposer provides accurate information about product specifications. The disposers' reimbursements for their used products depend on the demand for the discarded products, and their characteristics.

4.6.1 Inrego's supply of used and refurbished products

First of all, in order to qualify as a supplier of used and/or reconditioned products, a company has to be registered by the government and offer a minimum of 20 IT-related products to be supplied. The supply side of Inrego is in turn divided into three major groups of firms: the disposing organisations themselves (the primary end users), and other intermediaries and/or reconditioners, such as Atea Logistics. When it comes to suppliers that have used the products in their own operations, Inrego centres on Nordic firms and public institutions with offices in other parts of Europe besides the Nordic region. From Inrego's viewpoint, this group of suppliers are both vendors of used products, and customers of Inrego's reverse logistics services.

The orders for pickup from the disposing organisations initiate planning and other operations at Inrego and their business partners, such as third party logistics providers, who ship empty load carriers to the disposers to fill, and which are then collected by the logistics service providers. Inrego and its collaborators put their efforts into making the handling of used units as convenient as possible for the disposers, who are not used to managing these according to the newly established systems for logistics and recycling of electronic waste. For that reason, the collection and reconditioning firms try to help the disposers by teaching them how to organise their assets and processes that are associated with materials handling at their premises. Due to Inrego's expertise, it and its partners prefer to have more of the disposers ordering the service bundle, which involves full integration and synchronisation of forward and reverse physical flows. This kind of configuration is beneficial with regard to full truckloads in both of these flows. Routines and the experience of drivers who collect the used products from the disposers' sites with the rolling load carriers make the materials handling more efficient.

However, many disposers are not acquainted with the benefits of having the same partner arrange the integrated replacement of used products for new ones. Most of the organisations that discard their used IT equipment have business relationships with separate actors, who are responsible for either forward or reverse physical flows.

As mentioned earlier in this section, Inrego purchases reconditioned units from the disposers and firms, that similarly to Inrego recondition and trade with these articles In an attempt to match the supply and demand of a particular model of IT product, it is crucial to have access to as many business relationships as possible. The information flows in the network enable efficient sales and procurement among actors who may frequently take the role of buyers and sellers, depending on the supply and demand conditions. The relationship between Atea

Logistics and Inrego is characterised by this kind of arrangement, although Inrego is more a frequent purchaser of the reconditioned products than a seller. Nevertheless, as the refurbished products come with a warranty on the functionality of the processor, other components and features require inspection at Inrego's reconditioning facility. This and other activities that are organised by Inrego are discussed in the following section.

4.6.2 The internal physical flow at Inrego's reconditioning facility

Irrespective of where the used products come from, each of them has to be inspected and identified. When the identification is finished, every item receives a set of assured characteristics such as price, product class, memory, processor speed, and other specifications, which are stored in the internal unit number. This unit number fulfils several functions. First, all types of article numbers attached to a product become a part of the internal unit number in order to enhance product tracing possibilities, especially with regard to the report on the costs incurred by product recovery processes and sustainability reports that are delivered to the disposers and authorities. Second, the internal unit number can be coupled with a shelf position or a pallet number, which is yet another internal article number of a higher order that is used to optimise the management of inventory as it enables tracking and tracing of the equipment inside Inrego's warehouse. For example, it is possible to identify all products and their specifications in a load carrier through the internal pallet number. Third, the structure of information, which serves as the basis of the internal unit number, makes it possible to assign the specifications extracted out from the products during the inspection.

Depending on which of the three main groups of suppliers (disposers, or reconditioning and trading firms) provided the products, one of two different routes will be followed inside Inrego's premises. When a product has arrived from a refurbisher or a broker, it is assigned an internal article number that is applied in order to tie the product to a shelf space, a load carrier, or a buyer. The reason why the product acquires an internal number immediately upon arrival is that it is controlled by the actor who shipped the article to Inrego. On the other hand, due to lack of thorough quality control with respect to goods from disposers, these products have to go through a detailed inspection and classification at Inrego. These operations start with a classification of the newly delivered articles into a number of product groups such as laptops, desktops, copiers, monitors, and docks. Accessories including keyboards, mice, and cables are put inside load carriers for electronic waste. As soon as the quantity of load carriers becomes adequate for economic transportation in terms of utilisation of larger load carriers and vehicles, the products are transferred to the recycling firms.

Another kind of classification occurs at this stage of the internal physical flow, as the used products are classified into items that are and are not able to store disposer-created information. Hence, the products that contain some information must undergo a process of data erasure. The same software that deletes the information in the equipment identifies the product specifications, and assists the technicians with instructions on how to handle the product in the next phase. To be more precise, the software uses already installed specifications of the models sold in the market in order to match them with the features of the product that is being tested. The price and related product properties in demand are distributed through inter-firm interactions. The sales representatives at Inrego transmit this information to the technicians, who use the data to make decisions with regard to product recovery options for a particular article. When the features of a product are inserted in the internal serial number, the product is given a grade as an additional characteristic. With respect to the sales and distribution, A-graded goods are preferably sold to end users, and B-graded equipment to other companies who trade and recondition used IT-related products. When the sold products are about to be transported to a buyer, they are wrapped in plastic film.

As explained above, in case the software is not able to delete all the data, an electromagnet erases this information. Moreover, in an attempt to secure prevention of any type of information retrieval or extraction, each article or component that goes through the process of data removal is cut into pieces. In an attempt to further guarantee data security for the disposers, Inrego's staff goes along with drivers who transport these devices to the facilities for materials grinding, under control of the recycling partner, Sims Recycling. The materials are then sent to the producers of raw materials, who combine their virgin and second-hand materials.

4.6.3 Sales of the reconditioned products by Inrego

There are two key types of buyers to whom Inrego sells the reconditioned equipment: secondary end users, and other firms that manage the refurbishment, marketing, and purchasing of products. An additional classification of customers is geographical/national. Thus, Inrego has a Swedish and Norwegian web shop through which buyers are able to choose products in accordance with their requirements. The web shop gives them the possibility to assemble the desired features and the respective components, such as monitors, copiers, adapters, mice, and keyboards, regardless of whether the products are new or reconditioned. The accessories and products may even come from distributors of new parts and products.

According to the Quality Manager at Inrego, from a sustainability perspective the end users in the Nordic countries are the best customers as they are economically and environmentally most profitable. This is because they are located very close to Inrego's facilities in Sweden. Nevertheless, since the end users in the Nordic region demand the most recent models of IT equipment, the majority of reconditioned products are bought by intermediaries who market these units to end users in Eastern Europe. It is often the low price associated with the reconditioned articles that attracts these customers.

Since Inrego is not able to market all of the products it purchases from disposers to secondary end users, more than 50 per cent of the products are distributed through intermediaries. Apart from being experts in the demanded product specifications with respect to their geographical coverage, these intermediaries facilitate communication between the end users and Inrego. The business relationships between the intermediaries and their customers provide an opportunity to transmit the customers' requirements for a certain computer model to Inrego before the product is disposed of by a primary end user, or acquired from a reconditioner or a broker. From the viewpoint of Inrego's intermediaries, Inrego's relationships with the disposers serve as a means by which to provide access to the source of the used units. A large number of relationships with disposers increases the chances of finding the appropriate product for Inrego, the intermediaries, and the end users.

The implementation of an integrated approach to forward and reverse physical flows decreases the need to look for products in general, especially with regard to items from other brokers and/or reconditioning companies. Since the precise information about the product's status becomes available to Inrego before it is disposed of or delivered to Inrego's premises, it can be resold prior to being reconditioned. Nevertheless, many of the reconditioned articles are stored because, among other things, economies of scale have to be taken into consideration during the transportation, and the buyers have to receive the requested number of products that have same or different specifications, lead and delivery times.

4.6.4 Organisation of distribution from disposers to secondary users

A number of third party logistics providers supply their services to Inrego. The difference in their transportation solutions is a major factor contributing to the establishment of business relationships with these providers. Owing to the fact that these companies have developed specialised competencies in particular arrangements, Inrego has gone from performing some of the logistics operations on its own to outsourcing all collection and transportation completely.

Therefore, when it comes to organising and executing integrated collection of used products and distribution of new IT equipment, Inrego cooperates with Jemacon Logistics and IT Logistic (a firm that specialises in the integrated collection of used IT products and delivery of new ones). Apart from providing this customised logistics service, the load carriers utilised in these arrangements are not adjusted or modified with regard to routinised processes and standard load carrier size of the largest logistics service providers.

When there is a need for an assignment that requires the transport of palletised products from a certain sender to a particular receiver, Inrego collaborates with Schenker or Posten. The Quality Manager argues that these two firms can perform this distribution activity at a lower cost compared to other logistics service providers. Furthermore, for express deliveries Inrego cooperates with DHL and UPS. When it comes to international projects that require management of collection of used products from a range of countries, Inrego collaborates with an intermediary of transportation services, a freight broker. This company coordinates reverse logistics processes with several third party logistics providers, who arrange for specialised and adapted logistics offerings within particular countries or regions. For example, a freight broker is employed when the used equipment is gathered by the logistics companies from the offices of the Nordic companies who operate on the European level. As stated above, the goods that are delivered to Inrego from the disposers or others can be distributed further to brokers. In the next section, a broker of the products supplied by Inrego, Once Again, is described.

4.7 Once Again: a distributor of refurbished products

Once Again was a firm (labelled as a broker in Figure 4.1 and 4.3) that specialised in the reconditioning, procurement, and distribution of second-hand IT equipment. The company was started in 1999 and went into bankruptcy in 2010, with 24 employees and sales worth 100 million SEK yearly. At its premises in Ronneby, Sweden, it handled 30,000 units of various types of IT equipment. It focused on providing articles from the excessive inventories of electronics producers and intermediaries, and reconditioned products. Its key sales argument was that these products were more sustainable in an economical and environmental sense compared to new equipment.

The main component of Once Again’s business model included joint projects with IT Logistic and Jemacon Logistics, involving coordination of reverse physical flows of products that were part of leasing agreements between PC assemblers and/or intermediaries, and the end users. These projects were frequently coupled with the synchronisation of forward and reverse distribution activities. Nevertheless, whenever a disposer chose to separately manage logistics operations for new and used units, Once Again worked with Schenker and Posten. The main reason for this choice was that these two firms were not as specialised in the integration of forward and reverse physical flows as Jemacon Logistics or IT Logistic.

With regard to the acquisition of used products from the disposers, Once Again competed with other companies that wanted to establish a direct relationship with the disposers, such as Atea Logistics. For instance, both Atea Logistics and Once Again competed in public tenders for the procurement of services connected to reverse distribution and reprocessing. At the same time, Atea Logistics collaborated with Once Again, since Once Again often bought reconditioned units from, and sometimes sold products to, Atea Logistics. In addition, both companies were partially responsible for the management of product returns in the Nordic region on behalf of Hewlett Packard, which regarded Once Again and Atea Logistics as ‘preferred partners’. Hewlett Packard’s European programme for returns management included items such as end-of-lease returns, and surplus stock of outdated models from the plants and warehouses.

When it came to processes that were carried on in Inrego's industrial unit for reconditioning, the products were inspected as the information inside them was deleted upon their arrival. However, in case the products were supplied by remanufacturers such as Atea Logistics, the disposer-created data had already been erased before the equipment was sent to Inrego's reconditioning plant. Nevertheless, even when the units came from other reconditioning companies, the features of products had to be tested, since Atea Logistics, for example, merely guaranteed proper functioning of the processor.

The result of the inspection determined the reprocessing alternative. The complete products that were deemed erroneous or were not in demand from the viewpoint of potential secondary end users were transported to the premises of the firms that disassembled the products and classified the parts into groups according to their raw-material content. Otherwise, in case the specifications matched the needs of new end users, the units would be cleaned and the tags attached to them removed. Then, software would be installed in accordance with the desires of the new end users or intermediaries. New modules, bought from the distributors of new IT equipment, could be fitted into the products, such as computers.

The major customers of Once Again – the public organisations – purchased different types of articles regardless of whether they were new or used. Hence, schools often purchased reconditioned equipment while the surplus stock was marketed to the regional and municipal administration. Once Again was a close business partner with the municipalities and regional authorities since it was not even required to participate in public auctions or tenders, which is often the case when organisations in the public sector procure goods and services. These organisations could therefore get their products delivered on short notice from Once Again, as there was no need to go through a tender each time a need arose for a new computer. One of the firms that handles deliveries in these arrangements is Schenker. Their role in product recovery arrangements is presented in the following section.

4.8 Schenker: a logistics service provider

Schenker is a global logistics service provider of processes that include all transport modes. For more than a century, a central element of its business model has been based on the consolidation of shipments from a number of senders of consignments. In addition to this service, Schenker provides management/planning and actual execution of inventory holding and transportation solutions, which are developed jointly with its customers.

Schenker has a turnover of SEK 14.7 billion annually, and more than 42,000 regular Swedish customers, to whom it distributes 17.4 million shipments yearly. Environmental and quality management systems, ISO 14001 and ISO 9001, are widely applied in Schenker's operations. 10,000 people employed by Schenker are divided into two groups: those employed by Schenker itself, and those employed by the company's haulage contractors. In the relationship with the haulage contractors, Schenker coordinates logistics in relation to its customers, while the haulage contractors are responsible for the performance of activities related to the physical flows.

The relationship between the haulage contractors and the regional branches generates logistics services that are adapted to the local consignors and consignees. It is the accumulated knowledge acquired by the local employees at the regional offices that gives Schenker the possibility to manage the freight services effectively. For example, Schenker's regional branch has developed business relationships that have been working well for more than 10 years. In this way, Schenker is able to make adaptations for every customer even though the routines do not exhibit large variations throughout Sweden.

4.8.1 Handling of customer orders

Irrespective of whether the sender or receiver of goods is responsible for the expenses of logistics services provided by Schenker, some or both of these parties have to communicate data about the consignment to Schenker and the respective haulage contractor. Therefore, each time an order is placed it has to contain information about the distribution/collection sites and times, and the volume and weight, in order for the managers at Schenker's office and the local haulage contractor to arrange and plan the logistics processes. These local transportation firms apportion types of vehicles in terms of their size, depending on the mileage and the period of time and distance required for collection and distribution of the shipments. Additional information that can be included with an order concerns advice on how to handle the products in an attempt to avoid any damage that could occur during the transportation.

The way orders are placed displays certain diversity. The actors that require logistics services vary greatly in terms of the volume, height, weight, pickup/delivery times, and order logistics services on an ad hoc basis. In addition to these customers with irregular need for transportation, there are senders and receivers of goods with pre-planned quantities of pallet positions that are reserved several months ahead, with predetermined collection/delivery times and locations.

The consignors or consignees with large and correctly forecasted volumes, such as Atea Logistics, have interlinked IT systems with Schenker. In order to exchange the right amount of data between firms, integration of the software is implemented by a centralised IT department. These technicians are responsible for the establishment of communication links that allow information exchanges to flow through a set of crucial parameters and associated classes, such as length, weight, breadth, dates, and addresses. With regard to pricing, vehicle selection, and choice of route (for instance, whether the products should be transhipped through a local terminal or not), the most essential features of the transported articles are location, volume and weight.

Therefore, as the content of the palletised load is not as significant as how much it weighs or how much volume it occupies, this information has to be provided by the senders and/or receivers in order to set the price for the transportation service. That is, this pricing method applied to the large customers (such as Atea Logistics) implies that a purchaser of transportation is debited for the distributed volume that is equal to the pallet position (with a weight of 780 kilograms and a height related to the height of a truck), although this position could be partially loaded. Apart from transporting fully occupied pallet positions (and therefore even other load carriers of a higher order), Schenker ships mixed consignments of variable volumes coming and going from various senders and receivers. These consignments are normally associated with higher profits.

Atea Logistics ships a stable quantity of pallet positions each day, which qualifies it to be regarded as a frequent and regular customer by Schenker. As a consequence of this regularity, Schenker and Atea Logistics have interlinked their IT systems through Electronic Data Interchange.[33] This integration means that Atea Logistics attaches transportation documents and unique order/article numbers to the articles, or the load carriers that contain the articles. The scanning of these tags makes it possible to share information about the state of the product in terms of its geographical position and expected delivery/collection time. Hence, the information system and the tags make it possible for Atea Logistics to keep track of its consignments at any point in time that a shipment number gets scanned. This can happen during the collection, during reloading at a warehouse, and at the end point.

In recent years, the management of deliveries from Atea Logistics to Denmark has been performed in an efficient and effective way from the perspective of information exchange among several organisations. The information that each logistics service provider obtains is dependent on what load carriers they handle, which decreases the administration costs for all actors that organise the physical flows. Thus, as Schenker only distributes load carriers – that is, pallets or cabinets – to the hubs of a Danish third party logistics provider, it is not given any information about the detailed characteristics of individual units, such as the address of the end user or the time at which this end user should receive the product. On the other hand, the data associated with each product inside the load carriers (such as information concerning the receiver of every unit) is distributed to a logistics service provider that transports the products from the Danish hub to the final destination.

[33] Electronic Data Interchange is a method for structured and automatic information exchange between IT systems or networks. It is related to a number of standards, which in turn can be utilised to replace documents such as bills of lading, cheques, and orders.

4.8.2 The logistics operations

The organisation of logistics by Schenker is based on the geographical separation of Sweden and other Nordic countries into a number of districts. The size of these districts is determined by the duration of collection and delivery processes, the volumes/weights involved, and the distances covered. In an attempt to increase the loading rate of the vehicles of different sizes, managers try to match these variable capacities with regard to the quantities that have to be distributed and collected by changing the frequency of a certain collection/delivery route. Therefore, this frequency is lower for the places in which firms and other organisations do not ship or receive relatively large quantities of goods.

With regard to the routing of a consignment when it has been collected from a sender, depending on its weight it can either be consolidated with other collected loads in the local hub, or transported directly to the consignee. For example, all of the collected shipments that have a weight of less than 1,000 kilograms are co-loaded in Schenker's consolidation terminal in Växjö. Thus, a heavy load can be transferred between a consignor and a consignee without any need for co-loading. Alternatively, several lighter shipments can be consolidated at a terminal after being collected, and jointly distributed to a terminal in another of Schenker's districts, from which the consignments are sent to individual consignees.

At Schenker's Växjö hub, collected packages are unloaded, weighed and measured on a conveyor belt. The next step is to place the packages into a box that has the measurements of the standardised pallet. This box is then co-loaded with other boxes headed for another regional terminal or the final destination, depending on the size of the co-loaded consignment.

The volumes that Schenker distributes on behalf of Atea Logistics are geographically limited to Norway and Denmark, as Posten Logistik alone is the only provider of transportation services in Sweden. With regard to new or reconditioned goods headed for Denmark, one and a half trailers is sent to Danish consignees each day, whereas Norwegian receivers of goods take daily deliveries of 7–9 metres of length extended across and up to the top of a truck. Furthermore, Atea Logistics handles reverse distribution activities related to LOOP services from both of these countries. The purpose of the following section is to present how one company, Sims Recycling, handles the material that is without any customer value as a complete product in LOOPs.

4.9 Separation of electronic waste by Sims Recycling

Sims Group is one of the largest recycling companies in the world, operating in both consumer and business markets of the recycling industry. According to the World Economic Forum in Davos, Sims Group is one of the top 100 companies in the world when it comes to achievements for a sustainable future. One of the divisions of Sims Group is Sims Recycling Solutions, which is a global branch of the Group that specialises in offerings aimed at organising and performing collection and recycling of a number of products, such as electronics, vehicles, and tires. Sims Recycling has a turnover of approximately SEK 45 billion, and 5600 employees. The Nordic section/branch of Sims Recycling has its headquarters in Katrineholm. In addition, Sims Recycling has both quality and environmental certifications in accordance with the standards 9001:2000, ISO 14001:2004, and OHSAS 18001:2007.

Sims Group was started in Australia, and its expansion to several continents was coordinated from its Australian office. The acquisition of a recycling firm in Holland, MIREC, made it possible for the company to grow in the European market, and to become acquainted with the current rules in European countries, such as the WEEE Directive. By 2012, Sims Group owned nine facilities for reprocessing electronic and electrical waste in Europe. Similar processes and machinery is used throughout the world. The Marketing Manager claims that renewals, upgrades, and technological improvements are often easier in large global companies than in minor local or regional firms.

The American and British branches of Sims Recycling were opened in 2007, enabling the global availability of their waste management services for disposers at more than 260 locations worldwide. This enhances its customer service, especially in relation to international firms that wish to have the exclusivity of a single partner for the disposal of electronics in an environmentally friendly way all over the world. While each household does not have to contact a firm for the collection of electronic waste, all organisations must have a certified and approved receiver of electronic and electrical waste. Thus, the division related to consumer and business customers is the most common classification of the disposers, both globally and in the Nordic region.

Apart from being supplied by the disposers themselves in accordance with the legislation and directives, Sims Recycling sources its electronic and electric waste from companies that are not under any direct impact from the legislation in one way or another. Many disposers in the European Union prefer to have the stability of a business relationship, particularly with respect to the regions that are regulated by a single, uniform directive, such as the WEEE Directive. Moreover, a large number of disposing organisations choose to have one interface to turn to. This is also the reason why Sims Recycling often gets contracts with disposers even when it does not have a recycling/disassembly facility in all of the countries where the disposing organisation generates electronic waste. In such a case, Sims Recycling outsources recycling to partner firms that have industrial units for recycling in that country.

The adaptations of products and services vis-à-vis the suppliers take the shape of continuous modifications of weight, volume, and classes of products and materials. This is done in order to enhance the efficiency of the inter-organisational arrangement, and to adjust a certain configuration with regard to the regulations imposed by the authorities. When the products are delivered from the suppliers, Sims Recycling provides a number of activities, such as marketing, purchasing, and handling of the physical flows related to dismantling, classification, reconditioning, and recycling of the whole products, components, and raw materials. Disassembly, collection, transportation, storage, disposal, classification, and material fragmentation are carried into effect in cooperation with the disposers of various sizes and needs, logistics service providers, and other reprocessing companies.

Sims Recycling uses several logistics service providers, which is mainly attributed to the differences in services offered by these providers. This is reflected, among other things, in the fact that some of them provide more frequent deliveries and collections from certain geographical areas thanks to balanced volumes between the locations. Other central factors that differentiate the selected logistics service providers involve their local knowledge and business relationships, and the level of specialisation and flexibility with regard to the transport mode and load carrier.

Besides providing services with regard to the physical flows regulated by the WEEE Directive, Sims Recycling's services include erasure of the disposer-created data, the safe handling of equipment from the viewpoint of information security, the creation and sending of reports on the content of the discarded materials to the disposers, counselling on appropriate product recovery options, and interpretations and disposer-specific adaptations of the WEEE Directive.

Thus, with regard to the first product recovery option performed by Sims Recycling, reconditioning, a product goes through a process of registration, inspection, distribution and utilisation. Once the product has been subject to registration in the information system, each part is thoroughly tested in order to be taken out and placed inside another used product, or kept inside the same machine, depending on the functionality of the rest of the components. All disposer-created data is erased, and a certificate of destruction is issued as proof that the information deletion has been successful. Sims Recycling modifies the recycling reports sent to the disposers in accordance with the features it considers the most central in terms of weight, volume, product model, and type of raw materials. Moreover, the collection of information about the characteristics of products that are in demand from the business partners supports decision making with regard to reprocessing alternatives during the inspection. The units that are demanded as whole, rather than raw, materials are thus sold to secondary end users. Sims Recycling considers its knowledge of what is marketable to be one of its services that can be offered to the disposers.

In case of the other product recovery option, recycling, as soon as a product has been evaluated as out of order, or not in demand, by a reconditioning company or a disposer, it is delivered to Sims Recycling's facility. The product is registered in Sims Recycling's information system by identifying the type of item and its features, which may be stored in the article number. Then, the components made out of hazardous materials are picked out of the products to be distributed to companies that have competence in handling these items. This classification is based on the technical details provided by the manufacturer, or the visual/manual expertise of the technicians. Therefore, the monitor screen is separated from the rest of the computer and sent to SAKAB in Örebro, where the thin fluorescent tubes inside the monitors are vaporised/incinerated. Batteries made of lead are transported to the facility of a company (Boliden Landskrona) that specialises in the handling of this material. Another recycling company, Saft in Oskarshamn, handles batteries made out of nickel, cadmium, and lithium.

When the hazardous materials have been removed, the product (such as a laptop) is shipped to a mill that crushes the product into small pieces and granules. The granules composed of distinctive materials undergo a range of tests/procedures for the sake of determining their precise content. Thus, in order to distinguish granules with a high percentage of iron from non-ferrous ones, a magnet is used. In an attempt to distinguish and physically detach aluminium from other materials, a 'reverse' solenoid is applied. Some of the plastics are recycled and some are incinerated. A fraction containing both plastics and metals that Sims Recycling is not able to separate is sent to another firm, Boliden Rönnskär, where it is divided by smelting. At Boliden Rönnskär, the precious metals and copper have to be detached from other raw materials inside the IT equipment.

Generally speaking, the facilities of those who receive the waste from Sims Recycling are adjusted for one or several of the chemical elements out of which the products, parts, or shredded materials are made. Thus, adaptations on the demand side of Sims Recycling are made, in line with the raw materials content of the scrap. The purity of the materials is of great significance with regard to the requirements of the smelters. Hence, Sims Recycling is not allowed to mix zinc, copper, plastics, glass, aluminium, and steel in a single shipment without any consideration for the properties of the machines owned by the smelters. Since the printed circuit boards contain a blend of materials that can be processed by Boliden, these components are sent to Boliden's facility for the manufacturing of copper and other precious metals. Furthermore, in accordance with the requirements of Boliden Rönnskär, the length and breadth of the printed circuit boards are reduced to 40 millimetres each by shredding. Boliden also obliges its suppliers to send the goods in 20-foot containers, which is also a requirement that Sims Recycling follows when it ships the shredded printed circuit boards to Boliden Rönnskär. Boliden Rönnskär is a producer of metals from mined concentrate and recycled materials. The smelting process and other operations performed by Boliden Rönnskär are discussed in the next section.

4.10 Boliden Rönnskär: a reprocessor of electronic waste

Boliden Group is one of Europe's leading metals company, with a core competence in cost-effective and environmentally friendly exploration, mining, smelting, and recycling of high-quality metals. The industrial units within the Group work in accordance with the environmental and quality-management standards. Approximately 4400 staff are employed by Boliden, and the turnover amounts to around SEK 40 billion. Four mines and five smelters in Sweden, Finland, Norway, and Ireland produce a range of metals, such as copper (225,000 tonnes per year), zinc (30,000 tonnes per year), lead (24,000 tonnes per year), silver (500 tonnes per year), and gold (10 tonnes per year). With regard to the number of tonnes produced, the main metals are copper and zinc, although gold and silver have a major impact on the company's revenues.

The importance of copper is reflected in the fact that largest unit within the Boliden Group, Boliden Rönnskär, focuses on the production of copper cathodes out of the primary raw materials – that is, the copper concentrates from mines – and the secondary materials, such as electronic scrap and other types of waste. Boliden Rönnskär is one of the largest recyclers of electronic scrap in the world, and employs a total of approximately 860 people. This smelter, and the refinement plant that is located close to Skellefteå in northern Sweden, started with the processing of electronic and electrical waste at the beginning of the 1980s. In the following section, the supply and demand conditions at Boliden Rönnskär, as well as the operations at the facility, are described.

4.10.1 Management of supply and demand at Boliden Rönnskär

The supply of electronic recycling includes three groups of materials: printed circuit boards found in most of the electronics; electronic granules; and production waste from the electronics manufacturers. Electronic granules are made of low-grade electronic products, which are shredded, separated and upgraded by the recyclers to yield a non-ferrous material. These granules, which are fragments consisting of welded and tightly assembled metals and plastics, find their way to Rönnskär owing to the fact that they cannot be separated mechanically by the recyclers' machinery. The supply of all three kinds of electronic recycling materials to Boliden Rönnskär is described in the following section.

Supply of electronic and electrical waste to Boliden Rönnskär

Boliden procures electronic and electrical waste from around 25 of the largest recyclers all over the world, except for Asia where all materials consumed by the end users are transferred as waste to Asian smelters. The three largest recyclers and Boliden's suppliers in the Swedish market are Sims Recycling, Stena Metall, and Kuusakoski.

The deliveries of outdated electronic and electrical products in general, and the supply of this equipment regulated by the WEEE Directive in particular, are becoming an increasingly important business area for Boliden Rönnskär. This is mainly attributed to the growth of the quota of collected and recycled electronic waste in the European Union since 2005. Nonetheless, in general, supply quantities of the secondary raw materials – that is, electronic waste – are closely connected to the economic situation, owing to the fact that the growth rate of the collected volumes tends to stabilise and diminish during a recession. Thus, regardless of whether the supply of electronic scrap is regulated, it is heavily dependent on the progression of the business cycle.

Parameters such as the materials' properties, the consignment quantities, the geographical location of the mines, and the processing facilities, govern selection of the transport mode from the suppliers to Boliden Rönnskär. Out of circa 120,000 tonnes of electronic scrap delivered annually, 70,000 tonnes is transported by rail, 30,000 tonnes by boat, and 20,000 tonnes by road. The Swedish electronic waste is transported either by road or rail. In Sweden, Sims Recycling exclusively trucks its goods, Stena Metall solely uses the railways, and Kuusakoski transports its scrap by equally combining road and rail. According to a custom in the mining, extraction, and metals manufacturing industry, it is the responsibility of the supplier – in this case the recycler – to bear the shipping costs and administer transportation in cooperation with the logistics service provider.

As an exception to the rule of the metals production business that the supplier should arrange transportation to the consignee, it is Boliden, in its role as a receiver, that organises and procures an integrated railway transport solution. This arrangement involves delivery of finished products from Boliden Rönnskär to its customers, and the shipping of primary and secondary raw materials from the suppliers to Boliden. A third party logistics provider, Green Cargo,[34] coordinates the system, which takes the materials from Boliden Rönnskär to Helsingborg and back. In Helsingborg, the goods are co-loaded with other shipments in both directions; that is to say, to northern Sweden or to whichever continent the finished products are headed. The suppliers are then able to send their primary and secondary materials in the wagons, from Helsingborg to Boliden Rönnskär. These wagons would otherwise be empty.

The road transportation of the primary and secondary materials to Boliden Rönnskär is organised and performed by the suppliers and the logistics service providers, such as Schenker and Posten, although the goods are also delivered by many other, smaller, actors. Boliden has a number of requirements on how and when the products should be distributed, which are part of the negotiations between the Boliden Group and its suppliers. The suppliers forward these terms to transportations firms.

There is no single document that regulates all deliveries, and these issues are part of the negotiation between Boliden and each of its suppliers. Each means of transportation has its

[34] A provider of rail- and road-based freight transportation with unique know-how of railway logistics systems.

own set of requirements. Nonetheless, the general delivery terms and conditions governing the transport arrangement are more standardised than the specifications regarding the materials and other aspects with certain transactions. The delivery terms for the electronic scrap state that these products should be loosely loaded in trucks. On trains or boats, the goods must be loosely loaded, and preferably placed inside 20-foot large containers or other types of standardised railway containers or wagons.

The purpose of the load carrier requirements is to ensure that the goods are handled in a rational way during transportation, and when they arrive at the smelter. For example, the 20-foot container utilises the railway wagon optimally because three such containers occupy the space on a 60-foot rail wagon, implying an excellent match between the load carriers. Furthermore, since the 20-foot container was the standard load carrier for the integrated railway solution for distribution of the finished products to Helsingborg and the raw materials from the suppliers of Boliden, it was considered to be a suitable starting point for the construction of the new goods handling facility. The standardised load carrier was one of the rationalisations implemented when Boliden almost tripled the volume of electronic waste processed at its Rönnskär complex. The increased number of containers received (presently 20 containers per day) demanded a more automatic and rational means and facility by which to handle the physical flow at the Rönnskär complex. In addition, the containers themselves have to be swiftly unloaded, cleaned, put back on a train, and sent full to customers, or empty and unloaded to logistics service providers.

Apart from taking into account the economic and environmental sustainability in its selection of the transport mode (such as when a railway is selected over road transport), Boliden and its suppliers reprocess the materials in as environmentally friendly and cost-efficient a way as possible. Taking into consideration the economic and ecological dimension of sustainability, Boliden’s cooperation with suppliers of electronic waste is based on the principle of primarily reusing the product, and recycling it as the last option. Therefore, the suppliers are advised to control the products and try to sell them to the secondary end users in the same shape as they were bought by the primary end users in the first place.

Boliden Rönnskär is focusing its operations on a certain type of obsolete electronic and electrical goods, the printed circuit board, which is part of TV sets, mobile phones, DVD/Blu-ray players, printers, copiers and other office IT equipment. Boliden’s goal is to get hold of the precious metals in the printed circuit boards in as pure a shape as possible. As a consequence of its technology at the Rönnskär complex, Boliden obliges its suppliers to dismantle the products by picking out the printed circuit boards and shipping them to Rönnskär. In addition, the printed circuit boards are shredded into smaller fragments (40 X 40 millimetres (breadth X width)) by the suppliers, so that they can be processed almost immediately after the goods have been received by the personnel at Boliden Rönnskär.

If there were no actors performing these activities, Boliden would have to upgrade its own plant and invest in additional technology and equipment. The need for an intermediary between a disposer and Boliden Rönnskär may be clarified by providing an example. An organisational disposer, Ericsson, initially wanted to bypass the intermediary, Sims Recycling. However, Ericsson still had to distribute 200 tonnes of server stations to Boliden Rönnskär through Sims Recycling. The main reason for this indirect distribution was that Sims Recycling had to perform pre-processing in accordance with Boliden Rönnskär's requirements, since the server stations and their containers consist of aluminium, glass, and other materials, in addition to the precious metals in the printed circuit boards. Hence, the pre-processing executed by Sims Recycling meant dismantling, classifying the parts into distinctive fractions, and picking out the printed circuit boards in accordance with the requirements of Boliden Rönnskär.

Although many suppliers of the materials have comparable plants and apply similar techniques, each of them has a distinctive set of pre-treatment methods. As a result of these conditions, Boliden has to negotiate the plans and schedules with every single supplier. This means that Boliden does not have a universal set of requirements according to which all of their present and potential suppliers should operate.

Purchasing strategy and supplier relationships

The nature of the supply situation affects the purchasing strategy at Boliden. Thus, in contrast to the circumstances concerning secondary materials, and thanks to the existence of the spot market, Boliden has a greater flexibility in balancing supply and demand of the virgin materials. The spot market from which Boliden purchases approximately 20 per cent of the primary materials allows the company to make rapid adaptations in response to changes in supply and demand. Furthermore, the quantities of electronic waste to be delivered to Boliden are predetermined once a year, unlike deliveries of the primary materials, where Boliden has a greater opportunity to adapt to fluctuations in supply and/or demand. Nonetheless, the fixed amount of tonnes exchanged results in a relationship that displays stability and security, because both parties benefit in terms of acquiring ensured supplies and sales.

Boliden's purchasing strategy is based on having long-term relationships with a small number of large suppliers. In line with this approach, the number of suppliers of electronic scrap has been halved over recent decades. Moreover, Boliden Rönnskär only works with the first tier of suppliers, and never attempts to establish relationships with the suppliers' vendors, for the sake of avoiding direct competition between the suppliers at different levels of the supply network. Therefore, in the Swedish market, all suppliers that want to develop a relationship with Boliden Rönnskär are advised to first and foremost get in touch with Sims Recycling, Kuusakoski, and Stena Metall, the three largest first-tier suppliers, as seen in Figure 4.4. Boliden has been working with these three firms for more than 20 years, so they are always firstly offered the possibility to enlarge their capacity in case Boliden itself plans to expand its own facilities and volumes. During the latest expansion of facilities for the smelting and refinement of electronic waste, the first-tier vendors, Sims Recycling, Kuusakoski, and Stena Metall, were the first to be asked to increase their pre-treatment capacity. Interestingly, this is also the case with a relatively new actor, Sims Recycling, which, during its entry to the European market, acquired recycling plants with whom Boliden had well-developed business relationships.

In order to separate the first tier of suppliers from the second tier, Boliden has developed a number of requirements that the first-tier vendors need to fulfil. The shape and particularity of the component, the printed circuit board, implies that the supplier has to possess the technology and facilities to classify waste, separate the demanded fractions, take out the printed circuit boards, and shred them into pieces in accordance with the features of the machines at Boliden Rönnskär. The quantity requirement concerns a minimal annual volume of 1,000 tonnes of shredded printed circuit boards, even though this quantity has declined somewhat as a result of the economic crisis. Nevertheless, Boliden's policy, which discourages direct competition among suppliers in the network, does not allow the second-tier suppliers to become Boliden's own vendors, even when the quantity requirement is satisfied.

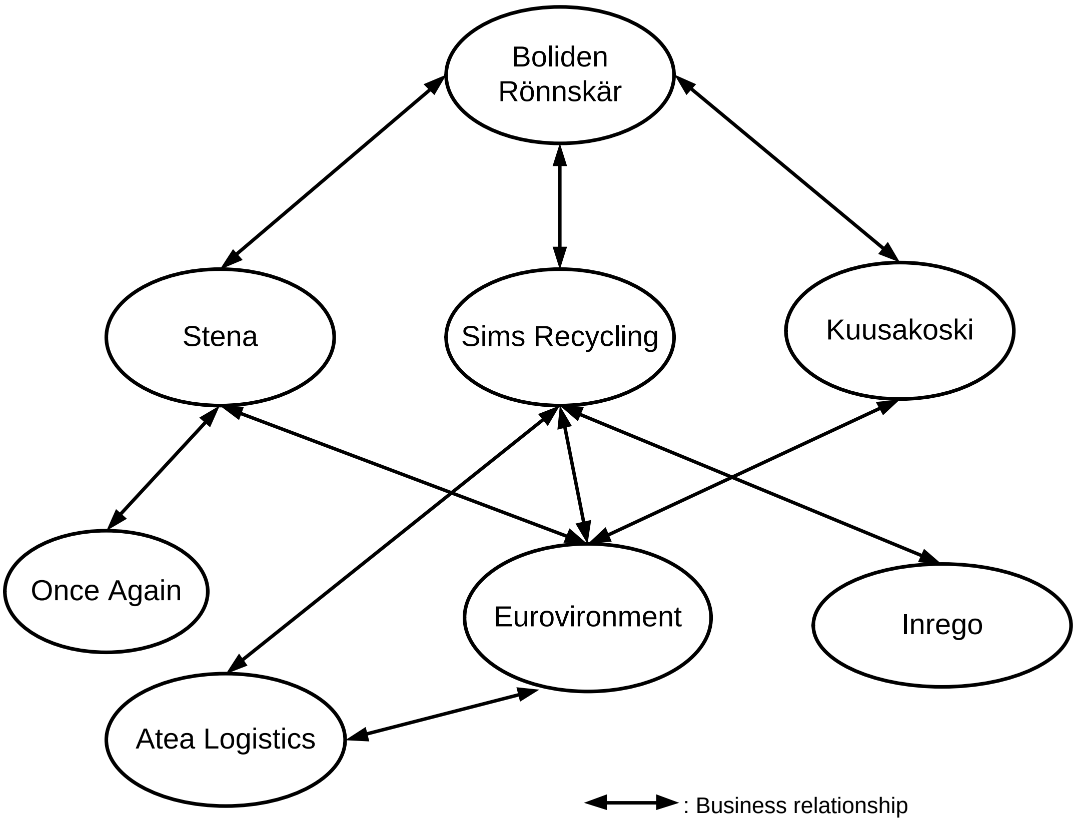


Figure 4.4 The structure of the supply base of Boliden Rönnskär with regard to recycled items.

A number of benefits relate to working with a small number of first-tier suppliers, and having the overall supply base structured in fixed tiers in an attempt to promote cooperation throughout several levels of the supply network. First of all, a larger number of suppliers is coupled with an almost proportional increase in the administration and materials handling costs, and the number of employees. Second, there is a limited number of recyclers with the resources, in terms of facilities and knowledge, on how to pre-treat the raw materials that enable Boliden Rönnskär to quickly get started on the activities they perform on a large scale, such as taking the samples to evaluate, and smelting, the material. Third, although the prices of raw materials are continuously negotiated between the suppliers and Boliden, logistics, administration, classification and production activities become progressively adapted between the businesses as the parties come to be closer partners. Therefore, Boliden has a policy in place to keep suppliers for at least three years, as no business relationship can work properly unless it is given some time to evolve, in order to strengthen the interdependence between the partners.

The element of competition is not completely erased even if policies that actively serve to discourage this behaviour are put into effect. Sims Recycling can make a decision to sell to the highest-bidding recycler in Europe. There are two smelters in the European market that are, to a great extent, direct competitors of Boliden in terms of the supply and the output that they produce: Aurubis from Germany and Umicore from Belgium. Furthermore, unlike Boliden and Umicore, the German recycler Aurubis has a completely different approach to purchasing in that it encourages competition between first- and second-tier suppliers.

On the other hand, even though the smelters compete directly with regard to a number of materials, they also sell and buy waste and by-products from each other. This is attributed to the fact that smelters are more skilled, and have more adequate equipment with regard to the limited range of metals that they produce. Hence, for instance, Boliden Rönnskär is more skilled at producing copper, zinc, and nickel compared to Umicore, which is more efficient in manufacturing palladium, platinum, gold, and silver.

Generally speaking, there is never, nor has ever been, a perfect match between supply and demand (in terms of smelting capacity). In their turn, these variations have a great impact on the business relationships and market behaviour in the industry. If there is a surplus supply, the smelters, including Boliden Group, are able to negotiate more favourable terms of trade in relation to the recyclers. On the other hand, in case of a deficit in supply, Boliden's purchasing strategy is to point out the importance of long-term business relationships in order to assure continuous and sufficient supply of electronic scrap.

Another purchasing strategy applied at Boliden is to rearrange the supply base in geographical terms in response to a drop in capacity utilisation below a certain reference point for any reason.

Thus, when a recession hits the European countries, the hardened competition for the secondary materials, and the overall lower quantities of scrap, make Boliden procure more from suppliers in other parts of the world. Therefore, when the volume of electronic and other scrap begins to fall in Europe, Boliden tries to buy more materials from suppliers in the United States and South America in order to keep its capacity utilisation as high as possible for the purpose of balancing supply and demand.

Furthermore, in an attempt to enhance a stable supply of printed circuit boards and run the smelting plants and blast furnaces at full capacity, Boliden tries to gather information on future trends in supply and demand, and forthcoming implementations of the directives on electronic and electrical waste. Greater precision in the forecasts is accomplished by, among other things, participation in European recycling committees, lobby organisations such as the European Electronics Recycling Association, and the conferences arranged by the recycling companies and authorities.

Integration of supply and demand

One of the largest challenges that managers at Boliden face is leveraging supply and demand. Therefore, the management at Boliden has developed a planning process, called a sales and operational process. The purpose of this process is to manage demand and integrate it with the supply, production, and logistics operations. Via the production department, Purchasing Managers receive information on how future demand is assumed to look. Adjustments in supply, production, and demand rates are continuously necessitating regular meetings between the respective departments. In addition to adjusting operating ratios of these organisational functions, the purchasing department has to guarantee that manufacturing will receive a mixture of primary and secondary input materials of concentrations of metals that fit the specifications of the machinery. Therefore, when the virgin ore does not have a sufficient amount of a specific metal, the purchasing department sources metal scrap and electronic waste with higher concentrations of that particular metal. The greater uncertainty with regard to the content of metals in the scrap in comparison to a more homogenous ore makes this activity a complex task.

The compilation of the forecasted supply and sales are sent to a planner, who is responsible for adaptations in buying an adequate mixture of primary and secondary raw materials. Thus, based on the current demand and available supplies, the purchasing and production departments calculate the monthly manufacturing rate and target inventory levels. The production rate, and hence demand, dictates how the inventory will be organised. One of the ratios that Boliden uses to optimise the inventory level is defined as the coverage time. Thus, the coverage time of 30 days at Boliden Rönnskär means that production should always have an inventory that covers 30 days of a particular input material available at hand. The Purchasing Manager brings together planned deliveries and inventory levels after monthly meetings with the production and purchasing departments.

Although inventory management at Boliden is about balancing continuity in production and low capital costs related to the proportionately low inventory levels, these levels are often higher than those in the component assembly business. This is attributed to relatively higher production downtime costs at Boliden, which may reach SEK 10 million a day, making Boliden prioritise the availability of materials for stable manufacturing processes. In order to maximise the capacity utilisation of the machinery, Boliden tries to make the Rönnskär facility operate at the same pace 24 hours per day throughout the year. In general, there is no producer of raw materials that can readjust to changing supply and demand conditions as quickly as the product assemblers, who usually also have a larger number of alternative vendors of parts that can step in if a single supplier fails to deliver. All in all, raw materials manufacturers face a longer adjustment time with respect to changes in demand, and thus in regard to given inventory limits.

Since most of the supplied quantities of electronic and electrical waste are decided upon and regulated one year in advance, it is primarily deviations in production that affect the variations in inventory levels. There is a forecasted sales prognosis and a delivery schedule for a future three-month period, as well as a long-term plan that covers 18 months. The management at Boliden considers three months to be a sufficient period of time to respond to long-term changes in demand, while at the same time providing a time window for the suppliers to revise their own delivery plans. In addition, Boliden’s suppliers can communicate actual and anticipated changes in supply on a regular basis every third month. As stated above, one of the strategic ways by which to cope with the decreasing supply due to a recession, for example in a certain geographical area, is to distribute the risks of uncertain quantities over several continents and countries.

A more hands-on approach to the integration of supply and demand concerns delivery notifications, which are used to distribute the information about delivery changes one month prior to the physical distribution of the materials. Thus, every supplier has to report to Boliden all the details of each shipment, and any problems (such as a fire, production failure, a sudden drop in the supplied quantities, etc.) that would cause delayed deliveries. The delivery notification is registered in the enterprise requirements planning system so that Boliden can control whether the promised quantities are delivered; that is, if the supplier is sending too-large or too-small volumes. The targeted inventory levels are measured in tonnes and monetary currency. This is essential for Boliden’s own inventory management, as the Purchasing Manager can compare the inventory levels with the scheduled deliveries and then provide feedback to correct deviations. The deviations are not allowed to exceed or fall short of the anticipated deliveries by more than 5 per cent. In case the supply deviations do exceed, or fall short of, the planned quantities on a more persistent basis, the production and distribution plans of Boliden, its suppliers, and its customers are affected as well.

There is a lot of communication between Boliden and its suppliers, even when a delivery schedule has been agreed upon beforehand. Any production downtime will result in higher inventory levels if the suppliers are not informed about the need to deliver reduced quantities. Since the suppliers of electronic scrap and printed circuit boards send a predetermined yearly and monthly quantity of goods, the inventory levels of these materials cannot be immediately altered. The Purchasing Manager has to wait for the end of the year in order to renegotiate the amount of supplies of electronic and electrical waste for the subsequent year, so as to gradually decrease surplus inventory levels over the whole following year. On the other hand, there is greater flexibility with regard to the deliveries of primary raw materials and resultant inventory levels, which can be changed more rapidly in accordance with demand and production. Nonetheless, thanks to efficient inter-departmental communication channels, as well as interactions with the actors on the supply and demand side, Boliden is able to sell 75–90 per cent of its products before the primary or secondary supplies are transported to the Rönnskär complex.

Another aspect of the integration of supply and demand relates to changes in prices. Boliden handles the risk of price fluctuations between the purchasing and sales price on the London Metal Exchange through the stabilisation of prices for up to 27 months; that is, for as long as the material is in the company's ownership. This means that it can be certain of not losing any money on the products, since the procurement and the sales price are same. It is the reprocessing fee that constitutes revenue for Boliden. This fee varies across the suppliers and shipments, and is paid for by the suppliers of both primary materials and electronic and electrical waste. Although the pricing of the used printed circuit boards is influenced by the amount of gold and the market price of gold, the heterogeneity of electronic scrap makes it necessary to negotiate the fee for smelting with suppliers on a regular basis. In contrast, the London Metal Exchange has a larger influence on the prices of the ore and the products coming from the Rönnskär complex, because they belong to standardised classes of raw materials that can be bought and sold on the raw materials markets.

4.10.2 Operations at Boliden's Rönnskär facility

Simply put, the manufacturing operations at Boliden are about classifying the supplied materials on the basis of their properties, and allocating them to the appropriate production machinery, such as furnaces. The output from the Rönnskär plant serves as input into the production processes of other actors.

Despite the great heterogeneity and material variations that characterise the electronic scrap, the processes for their handling are stable. More precisely, the methods for identification and separation of metals throughout the Rönnskär complex are standardised, and take their starting point in the dissimilarities among the behaviour of materials under different physical conditions.

When it comes to metals extracted from the waste and scrap, Boliden processes and manufactures copper, gold, silver, palladium, nickel, zinc, lead, and rhodium. Since these metals are blended in the used printed circuit boards, the quantity of each element has to be determined. Therefore, prior to any actual smelting, a sample of material has to be taken, evaluated, and priced so that the suppliers are refunded.

However, upon arrival, and before the sampling takes place, the electronic waste is unloaded by forklifts and transported to a discharging station, where the load carriers are weighed and cleaned. Thereafter, the material is transferred by forklift trucks to the sampling plant or shredder, depending on whether the printed circuit boards have been delivered pre-shredded or intact.

Sampling

Sampling is used to determine the content of the chemical elements in order to set the price on the supplies. Mechanised solutions are utilised as much as possible, since they result in proper and thorough testing. Selection must be done using automated equipment that can certify a statistically representative sample. The establishment of a statistically accurate method of sampling is a particular challenge with regard to electronic waste, which displays a higher variety and uncertainty in comparison to the virgin raw materials.

The first step in sampling includes determination of the size of the sample. There is a general rule of thumb that is applied in this context, which states that a carefully chosen volume of 5 per cent of a received shipment should be a representative sample. This rule of thumb, as well as the ad hoc decisions concerning the size of the sample, are influenced by a number of variables, such as the quantity, material heterogeneity, and the extent of administration per consignment and sample. Taking into consideration these facts, and for the sake of simplifying decision making, Boliden has settled upon a standardised weight for its invoice, which corresponds to a lot of 20 tonnes.

Every invoice is tied to a contract number for each supplier. In this way, the lots and their origin are kept separate so that every supplier is refunded correctly. However, the standardised weights and rules are not always applied, and some lots are evaluated on a case-by-case basis. Hence, for example, a boatload of 500 tonnes of shredded printed circuit boards will be divided into five lots of 100 tonnes, before the 5 per cent rule is applied to each of these 100 tonnes.

The actual activity of taking a sample involves mixing and shuffling the supplies in order to extract a section that is sufficiently representative of a larger quantity of a standardised load delivered to Boliden by the suppliers. Nevertheless, if the material is pre-shredded, it is immediately put into motion by a conveyor belt that directs the flow of a shipment in order to amass it for storage and transportation to manufacturing. At the same time, 5 per cent of the lot is collected for sampling from the conveyor belt. This procedure is called stream sampling.

The sample is then grounded down and melted in order to become solidified. The solidified piece of material is crushed into a fine powder, and 100 grams of this material is packed in a bag, which becomes representative for a lot of 20 tonnes. The powder is melted again in a laboratory and left to become a small artificial stone, which is dissolved and placed in cups used for evaluation of the sample. The content of various chemical elements is then determined by means of, among other things, x-ray and atomic absorption spectrometry.

The sampling methods and the content of the sample are documented and reported to the suppliers. Nevertheless, if the suppliers do not have full confidence in the procedures, they are advised to contact an external representative that specialises in monitoring and inspecting the sampling. In the long run, it is not economically feasible to control each shipment, lot, or sample by external representatives, since Boliden handles a vast number of consignments and orders. The trust that is built up in the long-term supplier relationships reduces the opportunity cost of frequent inspections. Therefore, as a business relationship develops, the frequency of spot checks declines.

Pricing, evaluation and classification of the supplied goods

The composition of chemical elements in a lot, which is determined by sampling, is an essential part with regard to the pricing decisions. The composition of materials in the supplied lots vary on a case-by-case basis; that is, between consignments and suppliers. Therefore, the processing and materials-handling fee that is paid for by the suppliers is a result of the extent of operations performed by Boliden Rönnskär on a particular consignment. The variation in reprocessing price depends on how difficult it is to process the material, and the composition of elements inside each lot. In other words, Boliden's transactions with suppliers are based on the reprocessing fee and the amount Boliden pays for the materials in a lot. The recyclers are charged with the cost of Boliden's operations.

For example, if a supplied shipment consists of a very heterogeneous blend that includes hazardous waste, which has to be handled in a special way, the reprocessing might cost more than 50,000 SEK per tonne. The waste handling, logistics, and production costs of such a lot could then exceed the price of the material. More precisely, the supplier would not get any money back, as it would only have to cover the costs of Boliden Rönnskär's operations carried out during the consignment. Boliden uses a grading system based on the concentration or weight of gold in relation to the total weight of a shipment of the printed circuit boards. Therefore, the market price of gold has a direct influence on the pricing and grading of electronic waste. The grading system in use includes three general classes: low, medium, and high.

In practice, it is the age and origin of the printed circuit board with regard to the product that it comes from that influences grading of the electronic waste. Although electronic products that are replaced frequently, such as TV sets, computers, and mobile phones, represent the largest quantities, the material content of these devices is of a lower grade than that of, for example, server stations. In addition, the printed circuit boards made under the most expensive brands are often high graded. The effect of the age of the printed circuit board, and therefore the product, is partly related to the business cycle. Due to the safer returns and profits related to gold, financial institutions have been pursuing investment in this metal since the beginning of the current recession in 2008. As a consequence of this behaviour, the price of gold has risen sharply, which in turn has generated powerful incentives to reduce the amount of gold in electronic products. This development has implied a general increase in the volumes of low-graded electronic scrap, which is detrimental for Boliden, which aims to acquire high-graded electronic scrap since this is associated with larger profits.

The significance of the material attributes varies with regard to Boliden's operations and facilities, and its suppliers and customers. Boliden has to process the heterogeneous supplied material regardless of how it was graded, while its customers demand the products that display properties of metals that are as purified as possible.

Smelting and raw materials manufacturing

This section focuses on how the supplied electronic scrap is integrated with the main physical flow of virgin metal ore for copper production, which represents the oldest, and still the main set of processes at the Rönnskär plants. This integration is possible due to the physical properties of metals – that is, the structure of their atoms – which can be melted in order to manufacture articles an infinite number of times.[35]

Although Boliden requires that its suppliers send the printed shredded circuit boards into a certain form, some are still sent to the company intact, and thus unadjusted with regard to the machines at the Rönnskär facility. This implies that Boliden has to perform cutting of printed circuit boards into the shape that the machines are able to process.

Boliden Rönnskär has developed capabilities in materials processing through four furnaces. Most of these are flexible and take a variety of goods. Therefore, if a furnace experiences downtime, or if it has to be serviced and maintained, other furnaces are able to compensate for the missing capacity. At present, Boliden runs two so-called KALDO furnaces[36] that handle electronic scrap. The convertor's most significant advantage lies in the capability to process

[35] Plastics and paper, on the other hand, change their material attributes each time they are recycled. Thus, for instance, pulp fibre becomes shorter after each recycling operation, implying a limit for this kind of material reuse.

[36] Top-blown rotary convertors.

various highly heterogeneous material mixtures, such as the electronic scrap. It is this universality that makes this technology especially applicable to the recyclable electronics materials.

Furthermore, the KALDO furnace is able to separate both plastics and metals in electronic granules, at the same time as the plastics become energy for the smelting operation. During the smelting process, the metal becomes detached from the plastics thanks to the difference in melting points of these materials. Moreover, the production rate of the KALDO furnace is largely determined by the quantity and type of plastics in the electronic granules.

The outcome of production in the KALDO furnace is adapted to the subsequent activity and the machinery that performs it – the converter. The air is blown in the converter so that it reacts with iron and other elements, apart from copper. As the iron and other substances, including sulphur, are removed in this process, the concentration of copper in the matte increases to 97 per cent.

After processing in the converter, the material is tapped and transferred to an anode furnace. Here, the oxygen is removed by adding ammonia and the copper content increases to 99 per cent. The copper is then placed into casts that form the anodes. When the casting is finalised, the anodes are processed by electrolytic refining so that the purity level of copper reaches 99.99 per cent.

As soon as the electrolysis is complete, the cathodes are removed from the steel plates and washed. Then, they are loaded on a train headed for Helsingborg. From Helsingborg, the products are distributed to the customers, such as the manufacturer of wire rods, Elektrokoppar. The integrated railway solution is used to coordinate the physical flow of copper cathodes from Boliden Rönnskär to Helsingborg for transhipment and secondary materials from the suppliers back to the Rönnskär plants. The delivery time of copper cathodes to Elektrokoppar in Helsingborg is one day. Since Elektrokoppar does not keep any larger inventory, it receives the cathodes daily. As a result of this cooperative effort, a production downtime at Boliden usually means a corresponding stoppage of operations at Elektrokoppar.

Waste management

Like any other company, Boliden generates waste and by-products, which have to be sent to a landfill. These materials involve hazardous substances: antimony, bismuth, arsenic, and mercury in the printed circuit boards, and the rare earth metals, such as neodymium, iridium, and yttrium, found in the magnets in hard drives and other electronic equipment.

The price of the rare earth metals is expected to increase; when this occurs, Boliden will develop processes for their extraction from the recyclable electronic materials. In addition, the fact that the rare earth metals occur in such insignificant quantities of the overall supply makes their processing unprofitable. The reprocessing profitability would be enhanced if the suppliers of electronic scrap and other recyclable materials would separate certain parts that contain higher concentrations of these metals, and amass them in economic quantities. In this way, the potential economies of scale in the processing of the rare earth metals at Boliden would improve. The Purchasing Manager at Boliden argues that the suppliers should take advantage of the fact that the percentage of rare earth metals is larger in relation to the total physical flow at the suppliers than at the Rönnskär complex.

The hazardous waste is a result of the production of both primary and secondary materials, including the processes of smelting and separation of metals from electronic scrap. All these metals end up in slag, which goes to landfill. In case Boliden is responsible for waste management, the hazardous metals are temporarily stored in appropriate buildings until a more sustainable solution in terms of an environmentally safe underground storage is constructed. For this purpose, underground caverns located at the depth of 150 metres will be built. These activities are performed in accordance with the rules of the Swedish Environmental Protection Agency for handling hazardous waste.

4.11 Summary

This chapter has presented the first part of the empirical findings of this thesis, in which the product recovery network around Atea Logistics has been described. More precisely, the company's joint planning, and management of reverse physical flows in a set of standardised service packages, LOOPs, have been discussed. These services include various product recovery options that are executed in accordance with different requirements of disposers. Some disposers replace their IT equipment regularly, while others place orders for reverse logistics services on an ad hoc basis. To facilitate proper organisation of the physical flows, information that is shared among the organisations is structured around the features of products, such as their specifications, ages, and collection/delivery times and sites. The widely adopted system for grading of the used and reconditioned products facilitates efficient communication and uncertainty reduction, which in turn enhances balancing of supply and demand.

The full integration of the forward and reverse physical flows from the perspective of disposers reduces administration costs and allows actor-adapted quantity and quality of information to be exchanged. In addition, as the firms that execute these processes arrange this information to be available to all the relevant organisations on time, and before the products are physically handled, the actors throughout the network are able to optimize their inventory, reprocessing, purchasing, sales, and transportation capacities and capabilities. The development of business relationships improves the chance of getting used and reconditioned products of appropriate form and quantity. The parties in these relationships can take the role of purchasers and sellers, and vice versa.

The used equipment is classified by a number of actors in the network, who apply specialised approaches to classify the products, and electronic and electrical waste. These methods for classification of articles are crucial in the direction of the products to appropriate facilities, where alternative reprocessing activities, such as reconditioning and recycling, are performed. Recyclers identify the types of materials that the products are made of in order to dismantle them and shred the separated material fractions. The purpose of classifying the materials is to achieve purity in the raw materials so that other actors can produce new raw materials. Recycling firms inspect the density, magnetic properties of products, and composition of materials inside the products. After each test, these materials can be transported to firms that specialise in treating particular types of materials, such as metals. As the tests proceed, the identity of a certain material group becomes more assured; these are transferred to the facilities for manufacturing of new products.

Logistics companies work with routine and improvised arrangements between all these facilities. Some firms, such as Jemacon Logistics and Eurovironment, are more specialised in a number of activities and resources associated with reverse physical flows, while other larger logistics service providers, such as Posten Logistik and Schenker, have the same approach in regard to both reverse and forward distribution.

5 ANALYSIS ATEA

This analysis applies the analytical framework of this thesis to the empirical findings of the case study of Atea Logistics and its handling of used products. The case analysis is structured in accordance with the three interconnected layers of the ARA model – activities, resources and actors. The activity layer is analysed by applying the concepts of transvections, activity similarities and activity complementarities, and crossing and differentiation points, together with the principles of postponement and speculation. Within the analysis of the resource layer, the 4R model is used to elaborate on resource interfaces, as well as classification systems and resource combining. Finally, the actor layer is scrutinised by discussing features of business relationships, actor positioning, and information sharing via classification systems in the network.

5.1 Analysis of organising product recovery in the activity pattern

The case analysis of product recovery in the activity pattern is based on the concept of transvection, which is presented in the theoretical frame of reference. In total, five transvections, which start at a disposer and finish at an end user or a recycler, are described and discussed in order to illuminate different reprocessing options, organising principles, and inter-organisational structures (Table 5.1).

	Product recovery/reprocessing option	Principle of postponement/speculation	End destination	Actors involved in addition to the disposers
Transvection 5.1	Recycling	Speculation	Manufacturer of copper wire rod	Schenker, Eurovironment, Sims Recycling, Boliden, Green Cargo, Elektrokoppar
Transvection 5.2	Recycling	Speculation	Manufacturer of copper wire rod	Schenker, Eurovironment, Atea Logistics, Sims Recycling, Boliden, Green Cargo, Elektrokoppar
Transvection 5.3	Refurbishing/ remanufacturing	Speculation	End user	Schenker, Eurovironment, Atea Logistics, Once Again, Posten
Transvection 5.4	Refurbishing/ remanufacturing	Speculation	End user	Jemacon Logistics, Atea Logistics, Schenker, Danish third party logistics provider, Broker
Transvection 5.5	Refurbishing/ remanufacturing	Postponement	End user	Jemacon Logistics, Atea Logistics, Posten, Inrego

Table 5.1 Transvections analysed in terms of their reprocessing options, organising principles, end destinations, and involved actors.

In Transvections 5.1 and 5.2, the laptops that have been disposed of are transformed into copper wire rod as the final product. A difference between Transvection 5.1 and 5.2 relates to the involvement of Atea Logistics, which processes the objects in Transvection 5.2 but not in Transvection 5.1. As objects coming from disposers in Transvection 5.1 are considered electronic waste, they are all directed and transferred to recycling facilities via Eurovironment. Transvection 5.2 illustrates the importance of coordination with regard to object classification, since the object in this transvection takes a detour to a recycling facility via additional classification and transportation to recycling.

In Transvections 5.3–5.5, the objects are remanufactured and resold to an end user. Another distinction among the transvections concerns the principles of postponement and speculation. In Transvection 5.3 and 5.4 the object is refurbished speculatively, while Transvection 5.5 operates according to the principle of postponement. The main difference between Transvection 5.3 and 5.4 relates to the involvement of diverse actors and information-sharing procedures between these actors.

5.1.1 Transvection 5.1 – recycling and speculation

Figure 5.1 is used to illustrate the actors (including the disposer, Schenker, and Eurovironment), activities (sorting (S) and transformation (T)), and resources (such as truck, hub, shredding mill) of Transvection 5.1, from a disposer to Sims Recycling. The used laptops in this transvection are shredded and separated into electronic granules that consist of a blend of plastics and metals, which become reprocessed into the copper wire rod. As depicted by Figure 5.1, a used laptop in this transvection is transformed into a number of outputs in addition to electronic granules by Sims Recycling.

To be more precise, this transvection, which is typical for LOOP 1, is focused on a laptop that does not contain any information that the disposer regards as sensitive. Another requirement for the assignment of a laptop to the particular facilities of this transvection is the evaluation by disposers and Atea that these objects are obsolete, or out of order. Thus, interaction between Atea's sales staff and disposers enables the disposer to make suitable assignments of objects to appropriate facilities, although there is no single organisational unit belonging to Atea Group (including Atea Logistics) that handles the objects physically in this transvection.

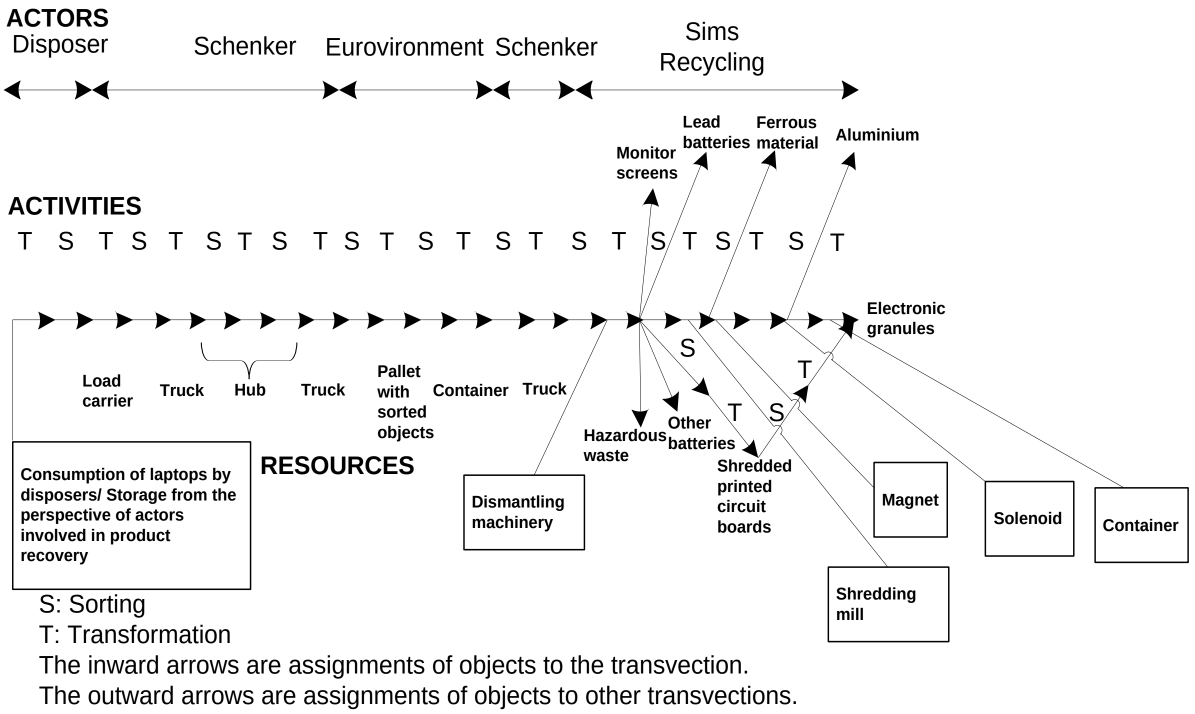


Figure 5.1 Illustration of Transvection 5.1 from a disposer to Sims Recycling.

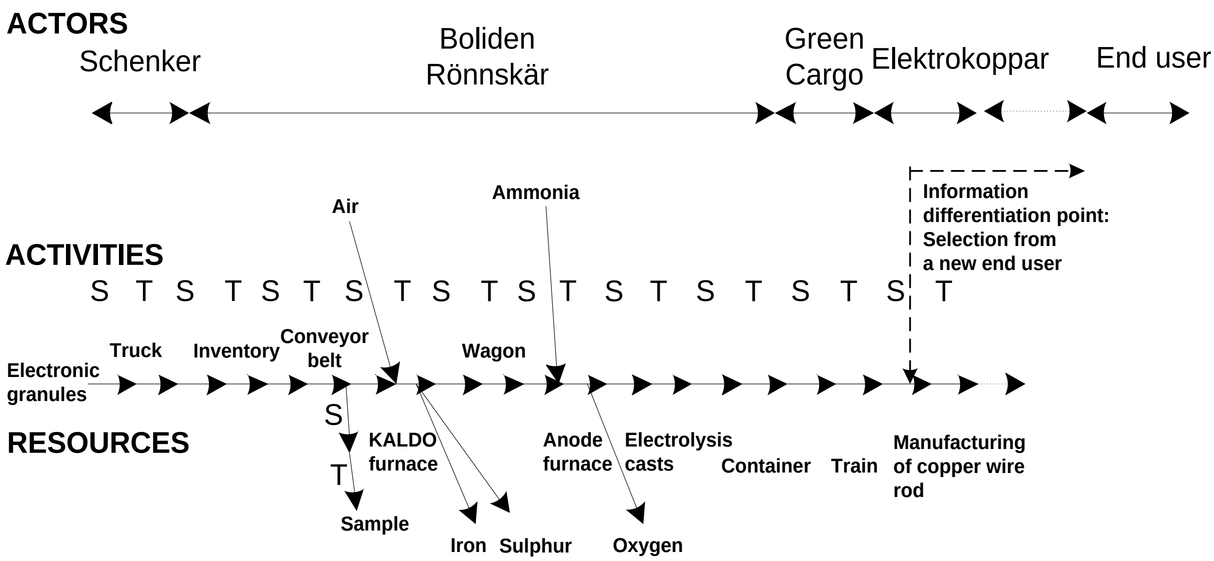
The disposer's order for reverse logistics services contains data on when laptops need to be collected, as well as their location, and the type of objects. This order is normally sent from disposers to Atea's sales companies, via Atea Logistics, and on to Eurovironment. Eurovironment transfers this information to Schenker for management (of sequential activity interdependencies) of the collection process of the object from the premises of the disposer.

The disposer assigns the used laptop to a load carrier, which is picked up by Schenker.[37] Schenker then assigns the laptops inside the load carrier to a truck, which transports the objects to a hub, as the quantity and activity similarities are not sufficient for direct delivery to Eurovironment's facility. At the hub, the objects are jointly assigned with other objects to Eurovironment's facility. When the objects arrive at Eurovironment's facility, they are assigned to a box with other objects of comparable characteristics from the viewpoint of the recycling company so that parallel interdependencies in the activity pattern are optimally exploited. At this point, the laptops in the box are assigned to containers for storage, to be transferred to the recycling facility of Sims Recycling where they are separated into material fractions. To conclude, within each assignment a decision regarding activity complementarity and/or similarity has to be taken.

[37] Depending on the quantity of objects, laptops are either assigned to Eurovironment's facility for physical object categorisation and breaking bulk, or to Schenker's hub for consolidation.

Sims Recycling disassembles (form transformation) and assigns laptop monitor screens to be transported (time and place transformation) to SAKAB, where they are incinerated; the laptops' lead batteries are disassembled and assigned for transport to Boliden Landskrona, while other batteries go to Saft in Oskarshamn. The dismantled printed circuit boards are assigned to be transformed in form by shredding. They are then assigned to a container to be transformed in time and place to Boliden Rönnskär (see section 5.1.2). Hazardous materials inside used laptops are handled in a similar way; that is, they are distributed to a firm that specialises in these outputs. Hence, the classification of objects determines when and where activities become complementary and closely complementary. The rest of the used laptops are assigned to a mill that transforms the form of the laptops by shredding. Ferrous materials are then assigned to a separate flow by means of magnets from the primary materials flow; materials containing aluminium are assigned a separate flow by means of a solenoid, leaving the detached flow of fractions of materials containing plastics glued to metals (that is, electronic granules), which cannot be separated otherwise than by smelting.

The electronic granules, which are one of the outputs of operations at Sims Recycling, gradually fill up a 20-foot container, which in turn is transformed in place by Schenker to Boliden Rönnskär (see Figure 5.2). This container exploits similarities and parallel interdependencies among activities.



S: Sorting
T: Transformation
The inward arrows are assignments of objects to the transvection.
The outward arrows are assignments of objects to other transvections.

Figure 5.2 Illustration of Transvection 5.1 from Schenker to the secondary end user.

In this transvectional analysis, the focus is on copper that has a purity level of 99.99 per cent as the final output, and the electronic granules as inputs to the processes at Boliden Rönnskär.

Thus, in order to continue with the transvection upon their arrival at Boliden Rönnskär, the electronic granules are assigned to a conveyor belt, which transforms the objects in time and place. They are then assigned to a temporary inventory and internal transfer – that is, transformed in time and place – to a sampling facility (five per cent of the input material) and to the KALDO furnace (95 per cent of the material).

When it comes to the sampling part of the transvection, the sample goes through several form transformations, in between which assignments are made based on the sorting and transformation rules of, among other things, the price system, the Periodic Table of Elements, The International System of Units, and the electromagnetic radiation spectrum. These classification, measurement and rule systems determine sequential interdependencies in the activity pattern, since different classes of objects are assigned to various resources and actors who control these resources, both internally and externally to an organisation.

The level of the copper's purity determines activity complementarities in the following sequence of processes. In the KALDO furnace, the air is assigned to the smelt so that sulphur and iron, among other elements, are selected or assigned away from the furnace in order to achieve a higher purity of copper during this form transformation. In order to increase the purity of copper, the smelt is assigned to a wagon and transferred to a site where it is assigned to the anode furnace. Here, the ammonia is assigned to the material during what is chiefly considered as the form transformation, in order to elevate the purity of the copper to 99 per cent, since oxygen is selected away from the material. Copper is then assigned to casts in which electrolysis takes place. The copper cathodes are transformed in the form dimension by cleaning to be assigned to load carriers, which are transformed in time and place to the site at which they are assigned to the railway wagons. The railway wagons (crossing points that utilise parallel activity interdependencies) undergo a transformation in time and place by Green Cargo, which arranges transportation of the copper cathodes to Elektrokoppar, where they are assigned from the trains to transformation in form so as to produce wire rods.

This transvection is governed by the principle of speculation, since the materials differentiation point is located at Elektrokoppar. This is also where the information differentiation point is to be found, as the end user places the order for an object when it is under control by Elektrokoppar. In other words, differentiation in the time, place, and identity of the end user occurs at Elektrokoppar. Time, place, and quantity uncertainty in supply and demand are managed through extensive interaction with business partners, while price is influenced by the raw materials exchange.

Activities in this transvection are complementary, all the way from the disposer of the laptops, via Schenker, and further down the transvection to Eurovironment, Sims Recycling, Green Cargo, and Elektrokoppar. The activities are closely complementary with regard to the end user from Elektrokoppar. The identity features of used laptops change in a predetermined fashion during this transvection, as objects are pre-assigned and preselected by the actors within it. Differentiation in form, on the other hand, is postponed until the load carrier associated with LOOP 1 arrives at Eurovironment's facility. Here, the used laptops are assigned to a specific box depending on the material content of the object.

Uncertainty in form, time, place, and quantity, combined with short lead times prior to the assignment of used laptops by disposers, create the need to stock the objects in hubs, or crossing points, where transformations in time are essential. Used laptops are collected by a small truck from disposers in order to utilise economies of scale in transportation related to shorter hauls. At the hub, the objects are jointly assigned to a larger truck. The truck as a crossing point is used to bridge time and place discrepancies at a lower cost per unit of weight or volume over a longer distance. Sorting according to the time and place dimension at Schenker's hubs and at Eurovironment's facility is crucial to parallel activity interdependencies in transportation. For this reason, parallel dependencies in crossing points are generated at several instances, such as pallets, boxes, trucks and other types of load carriers.

Different parts of this transvection require different kinds of uniformities. Between disposers and Eurovironment, the creation of parallel dependencies in time and place of crossing points is more significant than the creation of activity similarities in form features of objects. This is attributed to the fact that all objects in this transvection are regarded as electronic waste. The recycling firm that receives this type of object has to receive the waste in a form adapted to its facilities, and Eurovironment sorts objects on their behalf while keeping a more detailed differentiation of form in mind.

In order to achieve activity similarities in transportation from Eurovironment to the recycler, sorted objects in the form dimension share the same vehicle. Further along the transvection, Sims Recycling and Boliden Rönnskär classify objects physically according to even stricter and more detailed form features in order to determine sequential activity interdependencies and to achieve the highest-purity output possible (that is, copper in this case).

From the perspective of the electronic scrap – the electronic granules as the input and the copper cathodes as the output – Boliden Rönnskär's complex as a whole can be considered an aggregated crossing point. The level of aggregation of the crossing point can be extended to include inputs of both virgin raw materials and electronic scrap and generated outputs such as zinc, gold, and silver.

5.1.2 Transvection 5.2 – recycling and speculation

Transvection 5.2, illustrated in Figure 5.3 and Figure 5.4, is concerned with the path of used laptops from disposers via Eurovironment, Atea Logistics, back to Eurovironment, to Sims

Recycling, and finally to Elektrokoppar. The objects are handled by the same actors as in Transvection 5.1, until they reach Eurovironment's facility for the first time since it was regarded as saleable during its first sorting at Eurovironment. At Atea Logistics, the object is assigned to a facility for material defragmentation and shredding of printed circuit boards at Sims Recycling via Eurovironment, implying that it has to be transported for additional sorting at Eurovironment. Eurovironment, in turn, ships the used laptops to Sims Recycling. There is a sufficient level of parallel activity interdependencies for direct transportation of a trailer from the disposer to Eurovironment.

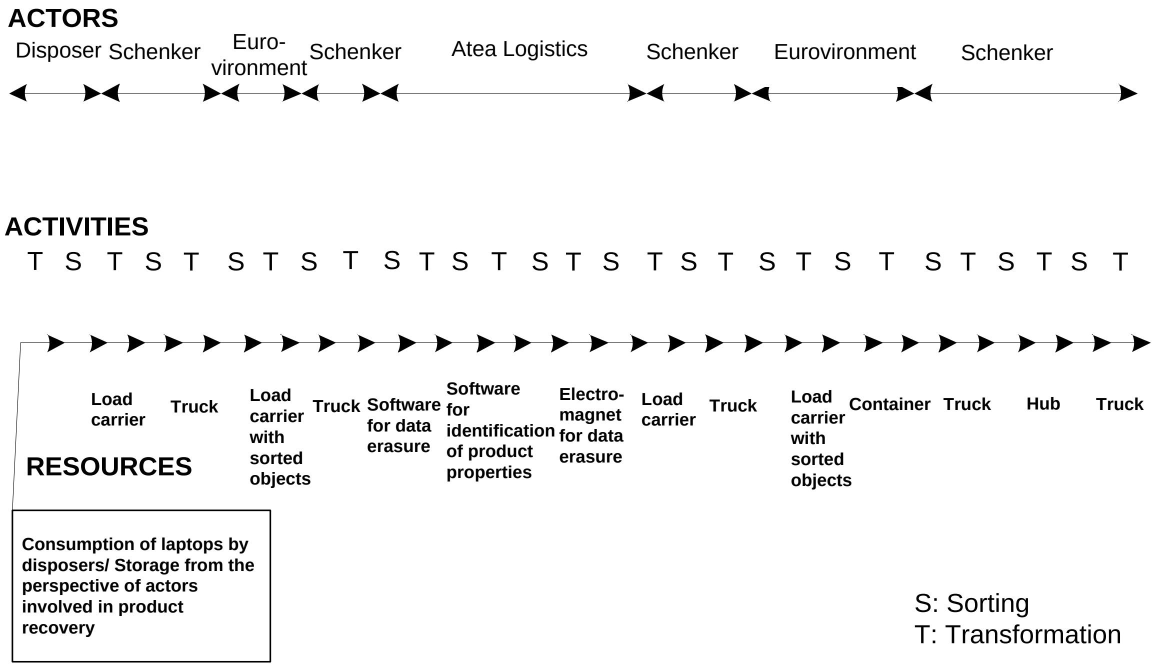


Figure 5.3 Illustration of Transvection 5.2 from a disposer to Schenker.

The starting point of this transvection is the disposer, who assigns the laptop to the load carrier; which is loaded onto a truck and delivered to Eurovironment. At Eurovironment, the objects are unloaded and assigned to boxes adapted to the requirements of either the recycling company or Atea Logistics. According to the rules established between Eurovironment and Atea Logistics, the objects in this transvection are those that could, at this moment, be assigned to the resources of Atea Logistics (more precisely, the properties of these used laptops match the requirements of Atea Logistics, and thus of new end users). The used laptops are then assigned to inventory, where other objects headed for Atea Logistics are stored. When sufficient volumes with regard to parallel activity interdependencies are achieved for economical transportation, the objects in the load carriers are assigned to a truck and transformed in place to Atea Logistics by Schenker.

After arrival at Atea Logistics' facility, the laptop is assigned to a resource that removes disposer-created data and identifies the properties of the object in the form dimension. In this transvection, objects with properties that do not match those desired may result in the products being declared non-functional, and the objects are therefore assigned to data erasure by an electromagnet. Then, the used laptops are jointly assigned to a pallet with other objects intended for recycling via Eurovironment so that parallel activity interdependencies are exploited. The object is kept at Atea Logistics' premises until it gets assigned to a truck, which transports this object back to Eurovironment in Enköping, Sweden. In accordance with Transvection 5.1, the objects are unloaded at Eurovironment and assigned jointly to a specific box with other objects that have similar material characteristics. These boxes are, in turn, assigned to a larger container for the sake of activity similarities in transportation between Eurovironment and the recycling facilities of Sims Recycling. That is to say, crossing points of a smaller size – that is, boxes – are placed into a larger crossing point – a container.

The first main difference between Transvection 5.1 and Transvection 5.2 is the greater uncertainty in Transvection 5.2 with regard to the form features of the objects, which go through two inspection processes. Transvection 5.2 is associated with greater uncertainty in the form dimension compared to Transvection 5.1, since not all objects coming from the disposers are regarded as electronic waste. Activities are hence sequentially interdependent from the disposer to Eurovironment, where differentiation in time, form, place, and identity occurs. As a result of the decisions at this materials and information differentiation point, objects become assigned to either Atea Logistics' or Eurovironment's facilities for transformation. Consequently, the form features of objects determine assignments and subsequent changes in identity. In other words, actors in the network control resources for sorting and transformation that are adapted to firm-specific object classes.

A helpful tool in Eurovironment's assignment of objects to Sims Recycling's refurbishing or recycling facilities is an agreement between Atea Logistics and Eurovironment that roughly regulates form features of objects that are exchanged between these firms. This agreement states transformation and sorting rules in qualitative dimensions of objects. As laptops and IT-related products are subject to short innovation life cycles, adjustments to the reference input/output values of object classes, together with transformation and sorting rules, are made continuously during the interaction processes. In other words, the classification system is being continuously adapted to characteristics demanded by end users.

Physical classification of objects at Eurovironment partially reduces uncertainty in the form dimension, to the benefit of Sims Recycling and Atea Logistics. Sims Recycling and Atea Logistics can therefore be more certain that they are getting objects according to their predetermined selections. That is to say, complementarity with regard to either Atea Logistics or Sims Recycling is confirmed at Eurovironment.

To continue with the transvection, when the object comes to Atea Logistics' facility it is sorted according to form features. At this point in time, activity complementarity towards Eurovironment and Sims Recycling via Schenker, which transforms shredded printed circuit boards inside containers in time and place, is established. Uncertainty in the form dimension thus creates a necessity to store objects at each stage in the transvection, with the intention of obtaining activity similarities in crossing points of various load carriers used in transportation.

Transvection 5.2 follows the same path, from Sims Recycling to Elektrokoppar, as that of Transvection 5.1, except for the fact that the objects in Transvection 5.2 are printed circuit boards taken out of the disposed laptops by Sims Recycling. The printed circuit boards are reprocessed in order to be delivered as copper to the producer of the copper wire rod (see Figure 5.4).

Classifications of the used laptops at Sims Recycling in Transvection 5.2 are identical to those associated with refurbishing at Atea Logistics, but not with regard to differentiation points when the objects (materials inside the laptops) are assigned to the actors that specialise in hazardous waste, glass, batteries, printed circuit boards, and fluorescent tubes in the monitors. After this differentiation, the leftovers from the laptops and other electronic and electrical products are shredded by a mill (a crossing point), in order to optimise the use of resources. Progressive differentiation occurs as aluminium, ferrous materials, plastics, and electronic granules are separated through the application of various classification systems based on the material properties.

Sequential coordination of complementary activities, in line with the principle of postponement from the perspective of Elektrokoppar, concerns this transvection from disposer, through Schenker, Eurovironment, Sims Recycling, Boliden Rönnskär, and Elektrokoppar, as the information differentiation point is placed at Boliden Rönnskär before the materials differentiation towards the end user occurs at Elektrokoppar. In this manner, postponement of differentiation in form, time, place, and the identity of the object with regard to the end user takes place at Boliden Rönnskär.

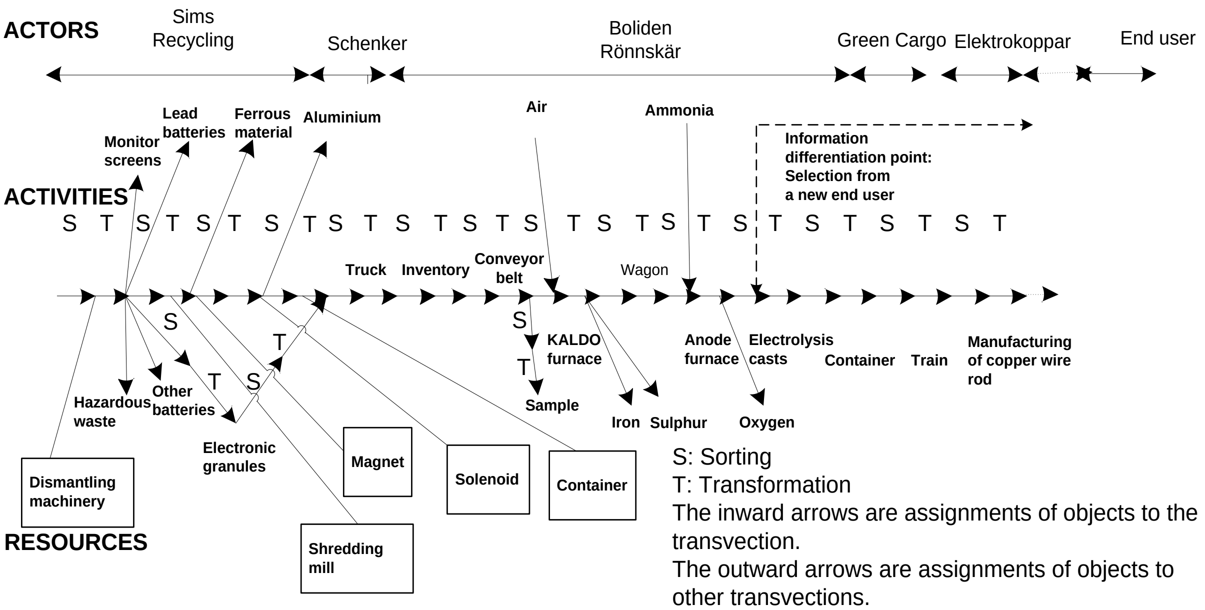


Figure 5.4 Illustration of Transvection 5.2 from Sims Recyclimg to the secondary end user.

The second main difference between Transvection 5.1 and Transvection 5.2 is the location of the information differentiation point with regard to the end user of the copper wire rod, in that it takes place while the material is being processed by Boliden Rönnskär. This means that activities become closely complementary at that point in time and place. The actual transformations in time, place, and form are delayed while the price and quantity are decided at the information differentiation points. Thanks to well-established relationships throughout the transvections, both supply and demand uncertainty are adequately handled. This is why Boliden Rönnskär can sell 75–90 per cent of its products even before the supplies reach its facilities.

5.1.3 Transvection 5.3 – remanufacturing and speculation

This transvection, which is presented in Figure 5.5, takes its starting point at the disposer that orders collection of each used laptop. The actors involved in the transvection are the disposer, Schenker, Eurovironment, Atea Logistics, Once Again, Posten, and an end user. Transvection 5.3 ends with the end user, who purchases the refurbished laptop through Once Again.

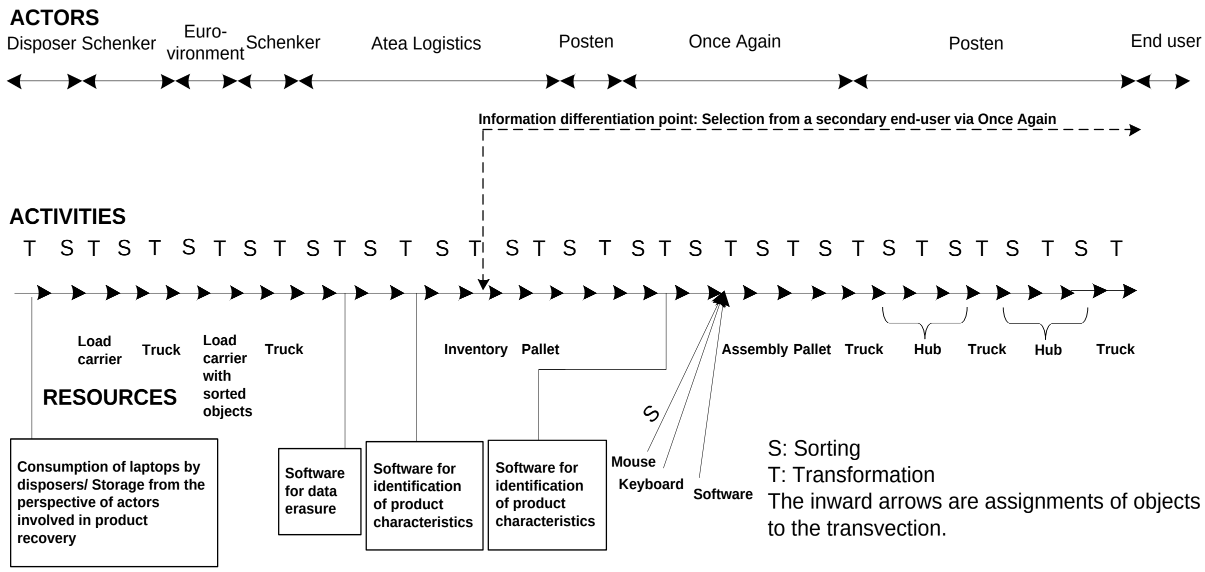


Figure 5.5 Illustration of Transvection 5.3.

Regarding the objects handled by the actors in this transvection, the disposer assigns any used laptops with information perceived as sensitive to a LOOP-specific load carrier with a padlock. Conditions surrounding the uncertainty of the objects are the same as in the previous transvection. Another condition concerns the quantity of the objects that are disposed of. Thus, in this transvection, it is assumed that the disposer possesses a sufficient volume of objects to facilitate direct transportation to Eurovironment, where the laptops are jointly transformed in crossing points in the form of load carriers involved in LOOP 2 and LOOP 3. According to the above-described transvection, Eurovironment assigns the object to Atea Logistics' facility, as the used laptop belongs to a group of objects that have been preselected by Atea Logistics. Consequently, the used laptop is assigned to a truck that transports this object to Atea Logistics' facility.

Together with other laptops, the object is assigned to another crossing point, a resource for form transformation, which deletes disposer-created information and identifies the objects' attributes, such as memory, screen brightness and price. In turn, this identification of object characteristics facilitates assignment to an inventory. After a period of time in the inventory at Atea Logistics, Once Again selects the refurbished laptop. The object is then assigned to the resources of Once Again as soon as it is picked from the inventory. From the loading area of Atea Logistics' premises, the refurbished laptops are assigned to trucks that transport objects on pallets to Once Again's facility. The pallets and trucks are used to exploit parallel dependencies and activity similarities.

When the object is unloaded at Once Again's premises, it is assigned to undergo additional identification of characteristics using software, as Atea Logistics only guarantees the functionality of the processor. Here, the objects are assigned to other operations, including the addition and assignment of new monitors, mice, keyboards, and software to the refurbished laptops. Physical delivery to end users is handled by Posten. Consequently, the refurbished laptop is assigned to a truck that transfers this object to a hub. Here, the laptop is assigned to a larger truck designed for long hauls to another hub. From this local hub, the object is assigned to a smaller truck, which carries the laptop to its final destination.

Transvection 5.3 follows the same route and same sorting decisions as those of Transvection 5.2, until the objects reach Atea Logistics. Eurovironment acts as a coordinator when it comes to quantities of objects shipped. Depending on a rule that takes distance and volume/weight into consideration, Schenker is able to send the object, either directly or through hubs, to Eurovironment's and Atea Logistics' facilities.

The direction of the transvection towards Atea Logistics is confirmed at Eurovironment according to the sorting and transformation rules in the form dimension, which are being continuously developed by both companies in the relationship. Thus, differentiation in time, form, place, and identity dimensions is postponed at Eurovironment due to uncertainty in the form features of objects. As the form dimension of each object is uncertain until it arrives at Eurovironment, Eurovironment must capture similarities among activities in crossing points of hubs, pallets, trucks, and other load carriers, which are related to uniformities in time and place dimensions of shipments to Atea Logistics. The used laptop in this transvection is therefore co-loaded with other objects in the LOOP 2 configuration. In this way, Atea Logistics, Schenker, and Eurovironment try to capture uniformities in time, place, and form features of objects with the purpose of minimising transportation and inventory costs (that is, overcoming time and space discrepancies) within these crossing points.

Information from Eurovironment and Schenker concerning the objects' features in the time and quantity dimensions is vital for Atea Logistics to ensure that sorting and transformation of incoming objects are carried out as efficiently as possible along the transvection. Utilisation planning of resources, such as labour and machinery, must be performed prior to objects' arrival at Atea Logistics. Atea Logistics reduces the uncertainty faced by Once Again, as the laptops' time, place, and form dimensions become definite through identification of the objects' features. Atea Logistics' facility accommodates activity similarities at the crossing points, as the same resources for transformation might be utilised in order to identify form attributes of many objects.

Concerning the storing of the object at Atea Logistics' facility, inventory holding provides time utility for Once Again, which can make selection consistent with the end user's requirements. The materials differentiation point towards end users is postponed at Once Again as it can assign monitors, software, mice, keyboards and other accessories to refurbished laptops in line with the needs of end users. This chain of activities can be performed efficiently, since the information differentiation point that initiated close complementarity occurred ahead of differentiation in form at Once Again. In this manner, customisation is combined with risk minimisation and scale-efficient distribution to end users. Logistics services on the supply and demand side of Once Again are performed by Posten. Hence, Posten and Once Again coordinate distribution operations before the objects' arrival, and after their departure from Once Again. By doing this, it is possible to balance the stock level so that deliveries can be secured.

To summarise, this transvection is coordinated intermittently between facilities as interruptions are caused by uncertainties in the form features of objects, and short lead times between order placement for the disposal and inspection of objects. This intermittent coordination is caused by insufficient and disorganised information sharing between disposers, reprocessors, and distributors.

5.1.4 Transvection 5.4 – remanufacturing and speculation

Transvection 5.4 begins at the disposer's facility with a used laptop. The object in this transvection belongs to a group of objects that require data erasure. Facilities involved in Transvection 5.4 belong to disposers, Jemacon Logistics, Atea Logistics, Schenker, a Danish logistics service provider, an international broker, and a logistics service provider. Furthermore, the used laptop is selected by an end user from Atea Logistics' inventory.

At the disposer's site, the used laptop and product-specific accessories, such as monitors, keyboards, mice, and cables, are all assigned to rolling load carriers by Jemacon Logistics immediately after delivery of the new laptops. The used laptops in the load carriers are then assigned to small pick-up trucks that transport the objects for a short haul to a hub. At this point, the objects in the load carriers are assigned, together with other objects in other load carriers, to trucks for a long haul to Atea Logistics' facility in Växjö,[38] following several levels of larger crossing points to overcome time and space discrepancies in an efficient manner.

At Atea Logistics' facility, the used laptop is assigned to software that modifies the form attributes of the object by deleting information and identifying its features, as portrayed in Figure 5.6. Sorting rules for comparison of object characteristics with those in demand facilitate assignment to subsequent resources for transformation. The used laptops in Transvection 5.4 are assigned to a pallet, which is placed in inventory. The Danish broker selects the object from the inventory by sorting objects according to their form features. Then, Atea Logistics assigns the object to a pallet, which is transported via Schenker and the Danish

[38] As the objects are unloaded, mice, keyboards, and cables are stored on a pallet until they are assigned to Schenker's truck, which transfers the pallet to Eurovironment's facility. These objects follow the path of Transvection 2.

logistics service provider to the broker. This is done together with other objects headed for Denmark.

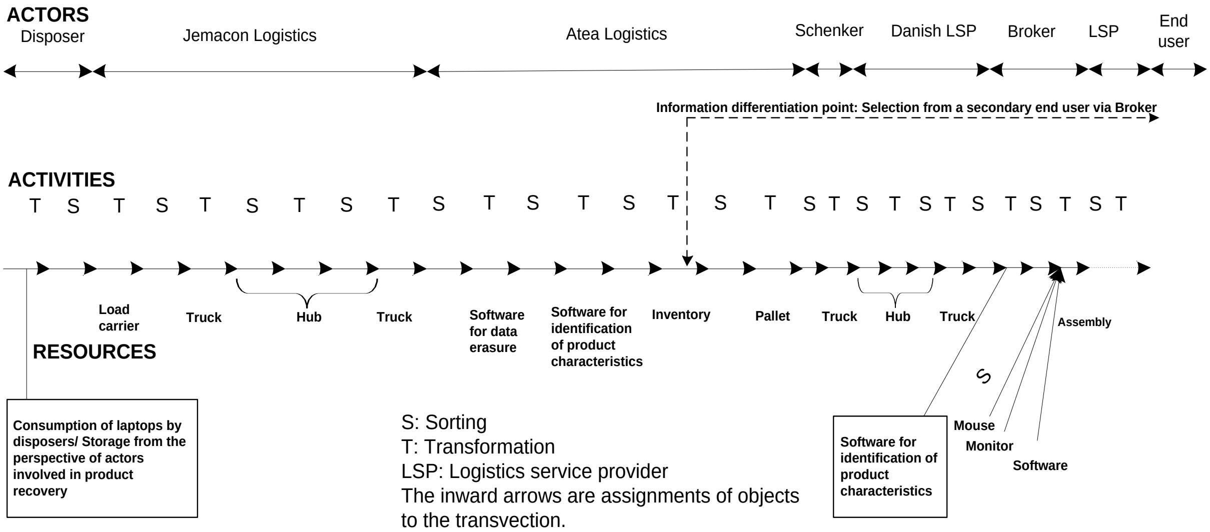


Figure 5.6 Illustration of Transvection 5.4.

There is a sorting rule for Schenker in Växjö that guides the assignment of objects to facilities. This rule states that if an order contains more than 1,000 kilograms, it does not have to be sorted at Schenker's local hub. As Schenker only transports the objects to the regional hub in Denmark, the company is not aware of the objects' final destination. Nevertheless, Schenker is informed about time and place dimensions of the objects and, to a certain extent, the form features of objects (such as weight, volume, length, and breadth).

From the regional hub, the object is assigned to smaller, short-haul trucks by another logistics service provider, who has received information on the broker's address and the object's delivery date from Atea Logistics. The broker then assigns other components and accessories, such as mice, keyboards, and software, to the refurbished laptop with the aim of differentiating the product in accordance with customer requirements.

Early provision of accurate information between the actors in the network creates opportunities for joint handling of parallel and sequential activity interdependencies. The management of activity similarities is conducted at the crossing points of various types: in time and place as in inventory and load carriers used in transport, and in form and identity when a certain quantity of objects that are alike in form are reprocessed with regard to the same end user. Transvection 5.4 is sequentially coordinated by disposers, Jemacon Logistics, and Atea Logistics until the object is tested and sorted in the form dimension after the transformation related to identification of form features. At this point in time, the object is not assigned any identity and is hence placed in inventory at Atea Logistics. Here, sales, purchasing, and inventory holding of objects display parallel dependence among activities.

Since Transvection 5.4 is characterised by the principle of speculation, the risk of unsold goods and consequent recycling is borne by Atea Logistics. Atea Logistics keeps the inventory of undifferentiated objects in time, place, and form features until orders for the objects are placed. This is where the object is located at the time for the information differentiation point. Sorting and transformation in time and place dimensions are then performed by Schenker and logistics service providers, while certain form transformations are carried out by the broker. The broker is able to make adaptations at the materials differentiation point towards end users through the replacement and/or upgrade of some parts that can be delivered with new mice, keyboards, software, monitors, and other accessories. The object is then transported to the end users by a logistics service provider.

Owing to the fact that Atea Logistics is deeply involved in the coordination of Transvection 5.4, that company acts as the provider of information to brokers and other actors in the network. Thus, in Transvection 5.4 Atea Logistics and Schenker share information only about the objects' pick-up and delivery hours and address between their own facilities and those of the Danish logistics firm. The Danish logistics service provider is, in turn, given information about the object's delivery date and final destination. As logistics service providers are not given any unnecessary information, the information is adapted to each actor's needs in order to guide the object through the activity pattern.

5.1.5 Transvection 5.5 – remanufacturing and postponement

In Transvection 5.5, a used laptop follows the same path as in Transvection 5.4, from the disposer to Atea Logistics. From Atea Logistics' facility and further down the network, the object is handled by Posten, Inrego and a logistics service provider. Inrego and Inrego's customer select the laptop before it arrives at Atea Logistics because information about the objects' time, place, form, and identity dimensions are known. Thus, sortings and transformations in this transvection, depicted in Figure 5.7, follow the same pattern as in Transvection 5.4 but the objects are not assigned to an inventory at Atea Logistics, as Transvection 5.5 is based on the principle of postponement. Instead, the objects are assigned to a truck almost immediately after sorting and transformation at Atea Logistics' testing and inspection facility.

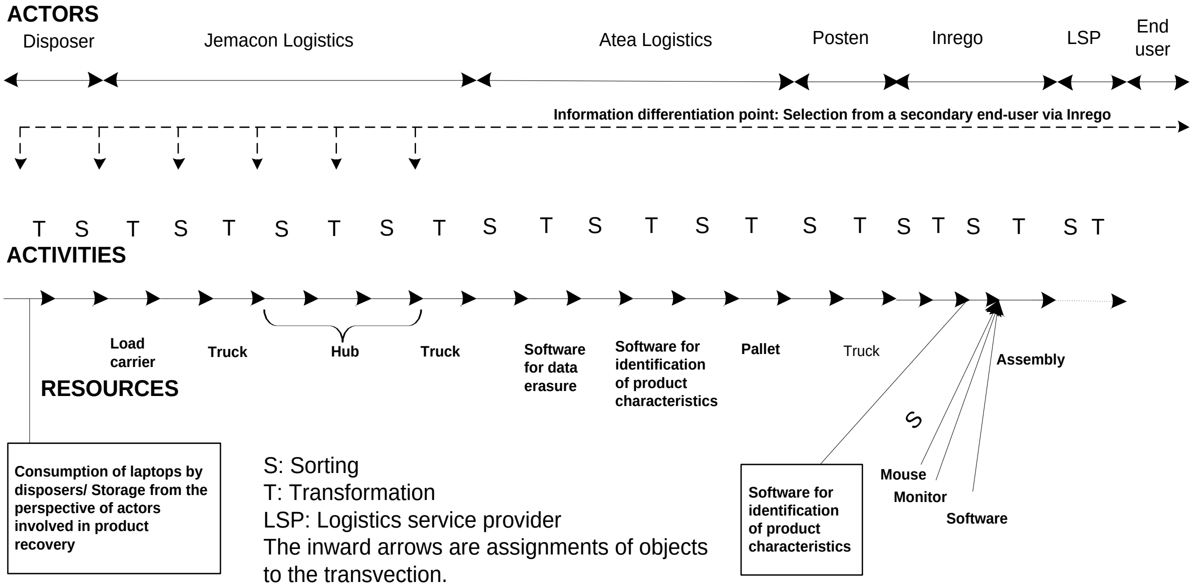


Figure 5.7 Illustration of Transvection 5.5.

The laptops are assigned to a resource for transformation that erases the data inside. If this transformation is successful, the object is assigned to a facility that alters or discovers (confirms) the object's characteristics in the form dimension. The used laptop acquires an article number that is used as a resource for sorting, since it contains information about the object. These data are then shared with brokers.

As transformations at Atea Logistics' facility are finalised, the object is assigned to crossing points in the form of pallets, which are transported on Posten's vehicles of various sizes through a range of transportation arrangements, depending on object classes and related values such as the size and weight of the shipment, in combination with sorting and transformation rules. In Transvection 5.5, the size of the shipment is sufficient for direct delivery by a single truck from Atea Logistics to Inrego. Inrego, in turn, can assign mice, keyboards, and software to the object at the materials differentiation point, which is then transformed during assembly.

Transvection 5.5 is postponed by differentiation in time and place, and, to a minor extent, form, at Atea Logistics and brokers. Many features in the form dimension of objects remain the same as when they were disposed of. Nevertheless, Transvection 5.5 is closely complementary, as the object is assigned an end user identity prior to its arrival at Atea Logistics' facility. Therefore, one of the key distinctions between Transvection 5.4 and 5.5 is that the identity of the object in Transvection 5.5 is end user specific as soon as it is dispatched by the disposer, which means that the information differentiation point is placed more upstream, for example, when the object is under operating control of Jemacon Logistics.

Uniformity in time, place, form, and identity, and the reduction of supply uncertainty, are achieved thanks to the regular replacement of a number of objects with comparable attributes in the form dimension, which are located close to each other at the disposers' sites. This uniformity creates opportunities to distribute the risks over several objects, and to provide information about the future availability of objects to brokers and secondary end users. However, it is not certain which object is selected by an end user with regard to each unique article number.

Regarding parallel dependency, activities performed in the physical flows of objects, and interaction processes involved in purchasing and sales of objects, are executed simultaneously. Brokers such as Inrego, and, by extension, end users, are able to place orders even when the objects are still at the disposer's premises, moving the information differentiation point further from the end users.

Thus, disposers in Transvection 5.5 provide exact information about objects to Atea Logistics a longer period of time before the collection gets ordered. Therefore, Atea Logistics is able to effectively coordinate activities and share information about the objects with other actors. For logistics service providers, information on form features, such as weight, volume, breadth, height and length of objects, are more essential than detailed description of attributes such as the size of the memory or the speed of processor. As Atea Logistics' transportation partner for Swedish deliveries, Posten, manages the entire logistics arrangement from Atea Logistics to Inrego's facility in Stockholm, Posten is given complete information about the object's entire path from a consignor to a consignee.

In summary, from the viewpoint of companies that are involved in product recovery, disposers maintain inventory in each of the transvections analysed. The actors try to find a balance between sequential and parallel interdependencies in the activity pattern in all transvections. Throughout the transvections, one of the roles of a particular actor is to transform object-specific data to other actors on its supply and demand side, so that informed decisions concerning parallel and sequential activity interdependencies can be made at crossing and differentiation points by the organisations that are handling the objects in question, in both an informational and physical sense. There is one major difference between Transvections 5.1–5.3, which were analysed in the first part of this section, and Transvections 5.4 and 5.5. In the latter transvections, there is a lower level of supply uncertainty from the point of view of Atea Logistics with regard to the time, place, form and identity features of the objects, owing to the fact that disposers provide accurate information about the laptops to Atea Logistics before the items enter the company's facilities. If the information differentiation point occurs before the materials differentiation point takes place at Inrego, it becomes conceivable to effectively combine activity similarities, together with the establishment of close complementarity towards an end user. In this case, it is possible for Atea Logistics to engage in long-term planning of its resources in terms of its capacity and resource utilisation. This is scrutinised in the next section of this chapter, which analyses the resource layer.

5.2 Analysis of organising product recovery in the resource constellation

The resource constellation in this section is analysed using the 4R model. As portrayed in Figure 5.8, a used laptop is the object, which is regarded as the focal resource in this analysis. Supported by the framework of the 4R model, the object's interfaces with other products, facilities, organisational units, and organisational relationships, are discussed in this section.

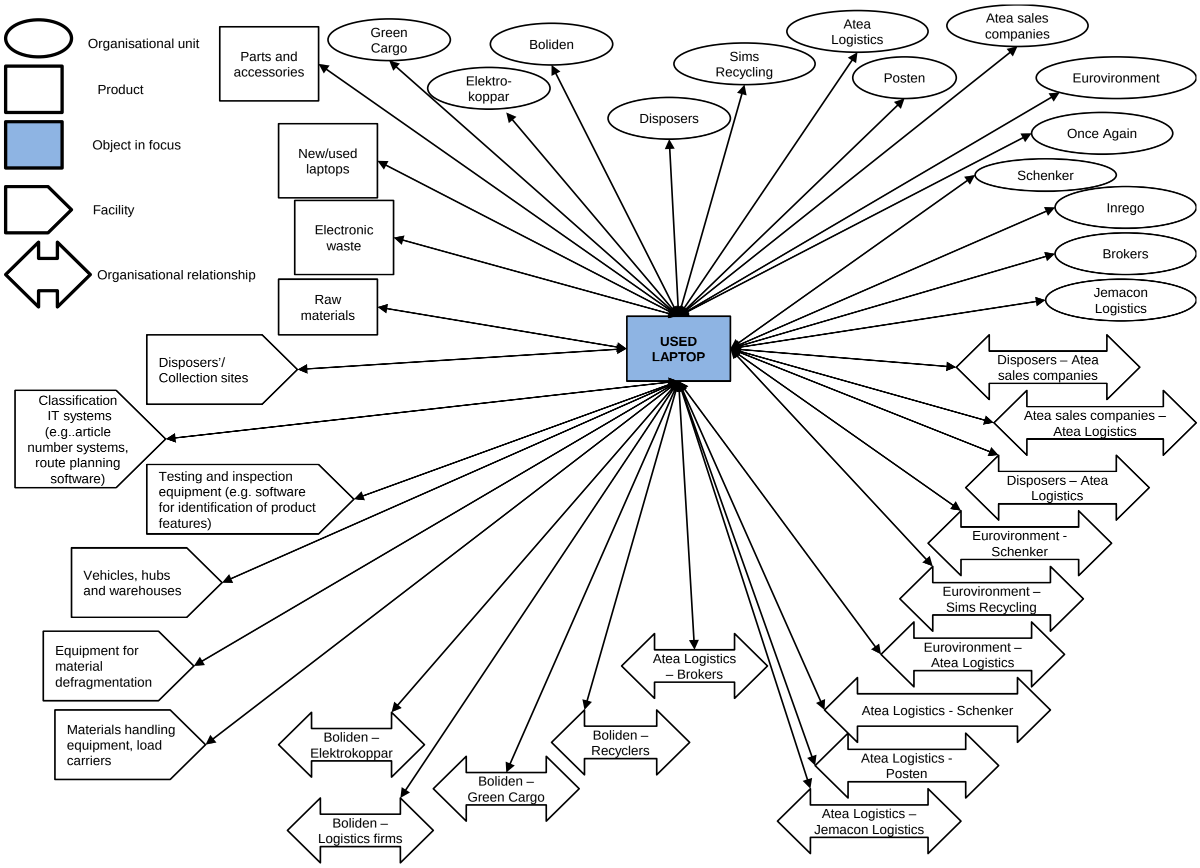


Figure 5.8 Overview of resources and their interfaces around a used laptop.

Figure 5.8 guides the reader through the analysis by providing an overview of the resources involved in LOOPs and related transvections. The object's interfaces with other resources are investigated in the associated subsections, and the first part of the analysis relates to the object's interfaces with other products.

5.2.1 The object's interfaces with other products

Objects such as laptops are fairly well suited to resource combinations involving multiple product recovery options, such as recycling, repair and refurbishing. The greatest tension appears in reverse physical flows for recycling in Transvections 5.1 and 5.2. As recycling requires extensive reprocessing and manual classification, tensions in resource combinations for recycling run higher than in resource combinations that involve other reprocessing alternatives. This is a consequence of the tight raw materials combination in laptop modules, which was designed to support efficient assembly for the sake of postponing product differentiation and customisation in forward supply, production, and distribution networks. On the other hand, the modular design that has been adapted for production–distribution networks of new laptops makes reprocessing options such as repair and refurbishing less laborious and time consuming, in comparison to recycling for both Atea Logistics and Sims Recycling. After all, it is less complicated to replace parts and modules than to manufacture new raw materials out of electronic waste.

During the distribution of low-priced (refurbished or new) objects and products in Transvections 5.1–5.5 over longer distances, it is crucial to use the space in vehicles as economically as possible. Hence, these objects are placed tightly together in crossing points in the form of wooden boxes, or in containers on wagons with the intention of utilising capacity as efficiently as possible. In addition, joint utilisation of crossing points, such as inventory and various means of transportation, by new and refurbished objects can reduce the costs of distribution.

However, operations associated with collection, classification, reprocessing, and transportation of electronic waste do not proceed without tension and conflicts. For example, uncertainty with respect to the quantity and form of objects results in the need for inventories in order to obtain economies of scale in transportation to a differentiation point – a facility for product classification. Inter-organisational coordination is essential, as objects with equivalent material characteristics have to be forwarded to various resource collections for reprocessing, distribution, and manufacturing of new raw materials, such as copper wire rod.

The object's interfaces with other products in Transvections 5.1 and 5.2

As Eurovironment steers objects into appropriate reprocessing resource collections in Transvections 5.1 and 5.2, common features of electronic waste from the disposer's perspective enable spreading of fixed costs, investment and capacity in crossing points. In other words, the focal object and other products share resources, such as facilities and the knowledge held by personnel, on behalf of other actors in the network. By utilising common features of electronic waste in terms of similar pick-up/delivery destinations and dates, it is possible to maximise the fill rates of trucks in all transvections that are analytically described here. This holds for the changes of object form features, since Atea Logistics, Sims Recycling, Boliden Rönnskär, and Elektrokoppar want to sustain and optimise their resource and capacity utilisation.

In Transvections 5.1 and 5.2, used laptops and other electronic waste retain features of raw materials that were used in their original manufacturing. However, these objects, whose use may vary widely, can complement each other during collection, classification, reprocessing, transportation, and production of the wire rod in crossing points. In Transvections 5.1 and 5.2, Green Cargo uses 20-foot containers on 60-foot wagons to transport electronic scrap, ore, and Boliden Rönnskär's output to its customers. Furthermore, in these transvections, objects classed as electronic waste are jointly distributed from disposers, via logistics service providers and recycling firms (Atea Logistics and Eurovironment), to the smelter and producer of copper cathodes (Boliden Rönnskär), and finally the manufacturer of the copper wire rod.

The supplied electronic scrap coming to Boliden Rönnskär has interfaces with gold, as the price of the supplied printed circuit boards and electronic granules is determined by the content and price of gold. Both The Periodic Table of Elements and the price system are crucial in this sorting. The price of a supplier-specific shipment to Boliden Rönnskär is also influenced by the amount of gold in the consignment, which is determined by the International System of Units (including grams, tonnes, etc.). The 'local' grading (classification) systems of actors are based on other general classification, measurement, and rule systems. These systems are resources for sorting, which in turn are stored and integrated with the systems of order and article numbers.

With regard to Transvections 5.1 and 5.2, the focal object and other products can supplement or compete with raw materials that do not originate from a recycling process. An example of supplementarity is the fact that the plastics within the electronic granules is incinerated and used as fuel in the KALDO furnace to melt the metal in the granules and the printed circuit boards.

The Boliden Rönnskär complex produces a variety of products out of the mix of virgin raw materials and electronic scrap that are used as inputs in several industries. Even particular raw materials, such as copper, are utilised in many supplementary applications, apart from being used in the copper wire rod. With this in mind, Boliden Rönnskär is both a material and information differentiation point, as its sales department arranges distribution ahead of differentiation in form as input for the production of 'new' raw materials and products, including copper, gold, silver, and zinc. When it comes to rare earth metals, the classification system in place does not support profitable production, since the quantity rate at crossing points in the form of machinery at Boliden Rönnskär is insufficient. This is why Boliden wants to require their suppliers of electronic waste – Sims Recycling, Stena, and Kuusakoski – to amass rare earth metals in greater quantities and then ship them to Boliden for more economically feasible processing.

The primary virgin raw materials and secondary raw materials, such as those coming from the printed circuit boards and electronic granules, may compete with each other, depending on (among other things) the progression of the business cycle. In case of a lack of raw materials, such as during a period of economic growth, competition will prevail from the network viewpoint. With respect to Boliden Rönnskär, depending on the rules of the classification system of objects applied with regard to the supply structure, the mined concentrate and electronic scrap might be completely supplementary at the facilities for reprocessing, smelting, and production of 'new' objects.

The object's interfaces with other products in Transvections 5.3–5.5

In addition to handling interfaces between the objects and other products, Atea Logistics manages interfaces between objects and their parts. The same labour force may perform the disassembly and reassembly of parts and modules. Moreover, software that identifies the features of laptop modules and deletes information inside of them can be used for parts and modules inside of other IT equipment, such as used printers. According to the same logic of exploiting comparable features of products in time, form, and, place dimensions, logistics companies, such as Schenker and Posten, can transport various types of both new and used objects.

Atea Logistics and Jemacon Logistics use interfaces that associate laptops, keyboards, monitors and mice together in load carriers with the aim of coordinating forward and reverse physical flows in Transvections 5.4 and 5.5. One of the benefits of this arrangement is that it increases capacity utilisation, as old equipment is collected simultaneously with the delivery of new equipment.

Interfaces of the classification system in Transvections 5.3–5.5 regarding object classes and related rules that involve competition between new and refurbished laptops are discernible at the level of Atea Logistics and brokers, as used laptops are offered together with new laptops and desktops. This competitive tension particularly applies in the case of Atea Logistics, which has a more direct connection with manufacturers of new products. Conversely, other types of new products, such as mice, keyboards, customised software, and parts/modules are complementary with used laptops. Assembly of accessories and parts takes place at the facilities belonging to various actors.

5.2.2 The object's interfaces with facilities

Objects and facilities are mutually adapted in many types of situations during the execution of LOOP services. Facilities such as load carriers are adapted to the quantities and features of laptops in Transvections 5.1–5.5 and the materials of which the used laptops are made. Therefore, when a disposer orders collection, the appropriate size, type, and quantity of the load carriers must be transferred from Atea Logistics. Thus, information about the object's features, transmitted by a classification system in the shape of a planning scheme, is of great importance for Eurovironment, which, jointly with Schenker, coordinates collection from the disposer's location to the reprocessing firms and/or brokers.

Difficulties may appear at different facilities in Transvections 5.2, and 5.3 as a result of uncertainties related to the objects' form features. Uncertainty about object features may create excessive transportation between disposers, Eurovironment, Atea Logistics, and recyclers, and unnecessary inventory handling in Transvections 5.2 and 5.3. On the other hand, inventories at Eurovironment, Atea Logistics and other actors are essential as a means of adapting classified laptops and other objects to input requirements of recycling and refurbishing machinery via the transportation of full truckloads or other load-carrying units, such as pallets and containers. These resource combinations are therefore developed with the intention of economising on vehicle space and minimising the number of loading and reloading operations.

Regarding load carriers that are used in collection, reprocessing, and distribution activities, laptops may share standardised load carriers, which are adapted vis-à-vis resource combinations related to transportation. During the collection phase, load carriers need to be adapted to the features of the disposers' site, and vice versa. Thus, load carriers in all transvections are adapted in their physical features to the size of doors, elevators and other construction standards at the disposers' facilities.

As the features of products in the resource combination concerning Transvections 5.3 and 5.4 are more valuable than in Transvections 5.1-5.2 with respect to information content and price, load carriers must be adapted to these types of used laptops in order to prevent the risk of theft. This adaptation with regard to altered product features is carried out by closing load carriers and equipping them with padlocks, which, in turn, usually means a decrease in the size of the shipment. As a smaller amount of weight, units, and volume of objects is transported and handled in Transvections 5.3–5.5, the space in vehicles is less efficiently utilised than in Transvection 5.1 or 5.2. Nevertheless, load carriers in Transvection 5.2 and 5.3 are compatible with each other in order to ensure they can use the same transportation and materials handling resources.

The object's interfaces with facilities in Transvections 5.1 and 5.2

Since the features of objects in Transvection 5.1 and 5.2 are not functional or saleable in their present state, load carriers in this transvection are primarily designed to enable the optimal utilisation of volume in vehicles and inventories. Therefore, transport damage to objects does not have to be taken into account when the goods are collected from disposers and distributed to recyclers. In this way, the load carriers used in Transvections 5.1 and 5.2 are those that are best adapted to existing logistics resource constellations out of all LOOPs. More precisely, the cages that are applied in arrangements involved in Transvection 5.1 and Transvection 5.2 are primarily adapted to the size of the EUR-pallet, which is adjusted to Schenker's transportation network, and designed for efficient materials handling at hubs and distribution centres. Moreover, Schenker's transportation network is adapted to these types of load carriers on several levels, such as containers and trucks. This standardised resource combination and large volumes make Schenker a scale-efficient partner for Atea Logistics and Eurovironment.

Electronic waste and used laptops usually have very low monetary value per unit of weight or volume, which are two attributes that have a great impact on vehicle utilisation and transportation costs. For example, this transport sensitivity of electronic waste implies that loading rates of vehicles are normally maximised, while unnecessary mileage and associated costs are avoided in Transvection 5.1. However, the uncertainty in the form dimension of objects in Transvection 5.1 creates a need for a materials differentiation point for inventory maintenance and classification of objects at Eurovironment to maximise the fill rates of trucks headed for recycling companies; that is, Sims Recycling. At Sims Recycling, the used laptops have interfaces with sorting resources, such as magnets, X-ray technology, and solenoids that use classification systems related to material properties to differentiate the objects in form. From this materials differentiation point object outputs must be adapted to the crossing points in the form of the machines owned by the receivers, who are then able to quickly start their own processes and achieve economies of scale in production.

Boliden’s materials handling facility with conveyor belts and mixing technology makes sampling, efficient allocation, and internal transfer to furnaces possible. The newly built KALDO furnace and materials handling facility are especially adjusted to electronic waste. KALDO furnaces are adapted to handle many kinds of materials, which make them well suited to the processing of highly heterogeneous electronic scrap. After this stage, in Transvections 5.1 and 5.2, the facilities, such as the anode furnace and electrolysis plant, are more adapted to the output object – the copper cathode.

From the recyclers’ and Boliden’s perspective, there may be difficulties in obtaining sufficient continuous volumes for the defragmentation equipment and smelting machinery, as accurate quantities and qualities of products are not completely known until after their arrival. Boliden Rönnskär handles this uncertainty by sampling, which uses facilities of laboratories, and classification systems related to X-rays, and atomic absorption spectrometry. In this way, the materials in the used laptops influence the facilities for the measurement of various elements in the laptops.

For example, in Transvections 5.1 and 5.2 three 20-foot containers fit perfectly on a 60-foot railway wagon. These resource adaptations and interfaces have an impact on the costs of recycling, as well as the costs of distributing the new materials, since Green Cargo tries to maximise the fill rates of the wagons on their way to and from Boliden Rönnskär. The 20-foot container was the reference point for construction of the new materials handling facility at Boliden Rönnskär. The shredding of printed circuit boards by the suppliers fits the machinery at the Rönnskär complex, which means that Boliden can proceed with its processes immediately after delivery of the printed circuit boards.

The object's interfaces with facilities in Transvections 5.3–5.5

In order to reduce damage to objects, and to make loading and reloading operations as easy as possible, the load carriers are adapted to the disposers' facilities. For these reasons, disposers are provided with instructions and rules on how to combine objects in load carriers associated with Transvection 5.3, so that the job of collection proceeds as efficiently as possible. In Transvections 5.4 and 5.5, it is Jemacon Logistics that, during collection, combines used laptops and other accessories in the rolling load carriers at the disposers' premises. The wheels attached to these load carriers enhance materials handling within the disposers' sites, as the load carriers themselves can be rolled in and out of the buildings. Moreover, these specialised load carriers create opportunities for leaner processes at hubs and refurbishing facilities.

A similar situation concerns distribution of adapted load carriers between Atea Logistics and Once Again or Inrego, and further on to the end users of the refurbished laptops. These objects, including used laptops, are adapted to Posten's logistics network, which uses standardised pallets that are also utilised for many other kinds of products. Conversely, rolling load carriers in Transvections 5.4 and 5.5 are more influenced by laptops, as these load carriers are especially designed to carry IT equipment without any undue cardboard packaging.

All in all, the quality and quantity aspects of objects are used to develop and formulate rules that guide the objects in the network toward appropriate facilities, such as testing machines, software for form identification, materials handling facilities, furnaces, and electrolysis plants, which are all adapted for the inspection of IT equipment and the raw materials inside of it. These facilities are either adapted to the features of objects as they were initially bought, or to features of modules and raw materials inside of objects. In this manner, certain form features of objects will guide the objects to facilities belonging to various organisational units.

5.2.3 The object's interfaces with organisational units

Manufacturers of new products indirectly influence objects and other actors involved in reprocessing and distribution activities via their rules for pricing. Furthermore, their product design methodology, which includes the choice of materials for ease of assembly, and thus disassembly, has a great influence on reprocessing operations. The choice of raw materials in the products affects the profitability of recycling. For example, if the amount of gold and precious metals that can be recycled is reduced in new products, so is the profitability of the recycling operations. The classification system used for grading of electronic scrap at Boliden Rönnskär is based on the weight of gold in the waste.

Public actors are influenced by, and influence management of hazardous waste and reverse physical flows. The Swedish Environmental Protection Agency administers the rules of the WEEE Directive and sets collection rates for used electronic and electrical products. The rules regarding electronic, electrical, and hazardous waste are enforced by the municipalities. The Swedish Recycling Industries' Association gathers the knowledge and distributes sorting and transformation rules from the authorities to the recyclers. At the same time, the recyclers may, through this association, show how regulations are working and what can be changed.

The involved logistics service providers, such as Schenker, Green Cargo and Posten, have the knowledge required to minimise overall logistics costs. Thus, logistics companies are concerned with how their facilities are managed, and how objects coming from various geographical locations and headed for a range of sites can be coordinated jointly at the crossing points and distributed at the differentiation points in time, identity, and place dimensions. This organising is supported by their competence in managing physical facilities, such as warehouses and materials handling equipment, and informational infrastructure such as classification, information, rule, and measurement systems. In particular, logistics service providers have expertise in the efficient physical handling of objects in standardised load carriers at their facilities. Thus, objects that are distributed in the same state as when they were bought, or as raw materials, do not have a notable impact on operations performed by logistics service providers.

Eurovironment is affected by used electronic goods because its personnel are familiar with sorting rules and testing machines. Furthermore, Eurovironment has skills in collecting and organising data about disposers and the features of their facilities. This information is stored in a system that continuously sorts and transforms pick-up and delivery locations of load carriers, so that Schenker's used-object collection processes may proceed as smoothly as possible. Disposers' skills in the purchasing of reverse logistics services, and their related knowledge in organising information about objects in form (such as age and technical specifications), time (delivery/collection date), and place (geographical location) dimensions affect resource combining and recombining. Organisations that manage reverse physical flows can use this information to plan their resource utilisation.

The object's interfaces with organisational units in Transvections 5.1 and 5.2

In Transvection 5.1 and 5.2, Sims Recycling is largely influenced by the used electronics and IT equipment in general, and by the used laptops in particular. When it comes to recycling, Sims Recycling's knowledge of how to sort and transform objects according to rules and values of both more general and more firm-specific classification systems is grounded in the features of the objects. The company's mill for crushing electronics is an example of an adaptation to accommodate efficient handling of used electronic and electrical products. Sims Recycling has a large impact on resource combining and resource recombining as it changes the features of objects through identification so that they can be differentiated with regard to actors that specialise in these inputs.

Two of these inputs concern electronic granules and printed circuit boards in Transvections 5.1 and 5.2, which have a minor influence on Boliden Rönnskär since their involvement in managing reverse physical flows of electronic waste represents a minor fraction of all their processes. However, their knowledge in evaluation, smelting and electrolysis of materials affects the used objects since they become valuable to the production–distribution networks of the 'new' products, such as copper wire rod. Moreover, the sorting and transformation rules with regard to the directives on hazardous waste influence Boliden Rönnskär, as these items have to be disposed of in an environmentally sound way.

National customs service organisations affect this kind of network in a more indirect sense, as the customs regulate international physical flows. For instance, these regulations have an impact on Eurovironment's and Sims Recycling's resource utilisation and expansion, as electronic waste is not allowed to cross borders freely. As a consequence of these rules, Atea Logistics' customers of new products in northern Norway have to ship objects that have been disposed of to Oslo for inspection, instead of sending the products to Eurovironment where they could jointly use Eurovironment's facilities for the same purpose.

The object's interfaces with organisational units in Transvections 5.3–5.5

Organisations that have precise data about the state of the object while it is in use provide opportunities for Jemacon Logistics and Atea Logistics to achieve integrated coordination of forward and reverse physical object flows, and to locate crossing and differentiation points for the sake of economies of scale in Transvections 5.4 and 5.5. Jemacon Logistics is, in turn, affected by used laptops because its logistics planning and execution expertise revolve around these objects. In addition, Jemacon Logistics' capabilities with regard to organising goods handling equipment, warehouses, and IT software, are built around laptops and other IT equipment.

Used objects influence Atea Logistics in terms of its expertise in operating software, and testing machines where sorting and transformation with reference input and output values reside. Supported by the classification systems, Atea Logistics can use the physical resources, such as materials handling equipment, utilised in reprocessing and storing objects before they are sent to brokers. Nevertheless, used objects have a minor influence on Atea Logistics, since the company is primarily concerned with distribution of new IT equipment. As Atea Logistics is dealing with used objects that are in almost the same form as those that are delivered new, the company does not experience the same difficulties as recycling firms who process the raw materials inside of used objects.

In turn, brokers of refurbished laptops in Transvections 5.3–5.5 are influenced to a great extent by the used objects. For example, in Transvection 5.3 Once Again had expertise in classification of these objects. Once Again's skills in inspection, reprocessing, and materials handling equipment are significant for the efficiency of the internal processes and crossing points. In addition, expertise in promoting used objects and providing information to Atea Logistics about the desired object features affects the direction of objects into distinctive resource collections at the differentiation points within the network. This exemplifies that resource constellations embed facilities, organisational units, and objects that are all tied together by means of the organisational relationship.

5.2.4 The object's interfaces with organisational relationships

Organisational relationships are a prerequisite for organising forward and reverse object flows. The organisational relationship between Atea's sales companies and disposers is an enabler of coordination between collection, reprocessing, and distribution, as disposers order reverse logistics services through the sales companies in all transvections. Used laptops affect the relationship between the sales companies and disposers only marginally, since sales companies focus on the distribution of new objects.

With regard to the physical flows in Transvections 5.1–5.3, the orders containing information about objects are transferred from the disposers to Atea's sales companies via Atea Logistics, and then on to Eurovironment. As a result, used laptops influence organisational relationships between Atea's sales companies and Atea Logistics, and Atea Logistics and Eurovironment. However, the used laptops are only physically handled in the organisational relationship between Atea Logistics and Eurovironment, which means that these objects have a larger impact on the jointly planned activities of these two actors than on collaboration in order handling between Atea Logistics and Atea's sales companies.

Organisational relationships between Eurovironment and disposers affect the collection of used laptops. Eurovironment has more detailed and updated data about the characteristics of objects at disposers' sites, compared to Atea Logistics. The information flow of orders (that is, the fact that Eurovironment receives orders from disposers via Atea's sales companies and Atea Logistics) can be examined in future. As of 2011, Eurovironment had a minor influence on the content of LOOPs and the choice of LOOP services in Transvections 5.1–5.3. Nevertheless, Eurovironment's relationships with disposers have so far contributed to enhanced detailed knowledge about disposers, which streamlines coordination of the collection process.

In Transvections 5.1–5.3, used laptops have an influence on the organisational relationship between Atea Logistics and Eurovironment, as these laptops and other IT equipment are the only ones handled in this relationship. The organisational relationship between Atea Logistics and Eurovironment is essential for Eurovironment, as Atea Logistics is its largest refurbishing partner. Moreover, interlinking and adaptations of classification systems between Atea Logistics and Eurovironment provide a means by which to exchange accurate data regarding available quantities of load carriers, pick-up/delivery dates and geographical locations of objects. In this manner, information sharing can reduce investments in potentially unnecessary load carriers by ensuring efficient utilisation of those load carriers that are already in use. An additional benefit of extensive information exchange in the network is the opportunity for capacity planning at Atea Logistics' facilities in relation to its other relationships with manufacturers, customers and brokers.

When Atea Logistics receives an order, it is transferred to Schenker so that Eurovironment and Schenker can arrange for the collection of the used laptops in Transvections 5.1–5.3. Thus, object features influence the relationship between Schenker and Eurovironment, as these actors organise loading and reloading sequences during the collection and transportation of used objects to Eurovironment's facilities. Further down the network, the organisational relationships between recyclers and Eurovironment, and between Eurovironment and Atea Logistics, have encouraged the development of sorting rules that direct the objects from the materials differentiation point at Eurovironment to Atea Logistics or the recycler. In addition, haulage to Eurovironment's and recyclers' (such as Sims Recycling) facilities must be coordinated so that the costs of logistics operations are kept to a minimum.

Posten and Schenker are responsible for deliveries of both new and refurbished laptops in Transvections 5.3–5.5, and Schenker alone for the delivery of electronic granules and printed circuit boards from Sims Recycling to Boliden Rönnskär in Transvections 5.1 and 5.2. Atea Logistics adapts refurbished laptops to Posten's facilities by packing them tightly in wooden boxes, which are compatible with the measurements of EUR-pallets. Hence, Atea Logistics is more influenced by the relationship with Posten and Schenker than the other way around, as refurbished objects coming from Atea Logistics' facilities are adapted to load carriers that are standardised in relation to Posten's and Schenker's transportation network. The electronic scrap is also stored in containers adapted to the facilities of Schenker's transportation network. This is done with the aim of maximising the fill rates of load carriers and making the processes as efficient as possible.

The organisational relationship between Eurovironment and the recycling firms such as Sims Recycling is of major importance for the efficient functioning of inter-firm resource adaptations of Transvections 5.1–5.3. Eurovironment classifies objects physically with regard to the equipment of recyclers, which, in turn, indicates that this relationship is affected by electronic waste.

The object's interfaces with organisational relationships in Transvections 5.1 and 5.2

From a network perspective, different actors in various LOOPs bear the risks and uncertainties associated with unnecessary economic and environmental disadvantages. In Transvection 5.1 and 5.2, Atea Logistics, Eurovironment, and Sims Recycling reduce uncertainty on behalf of Boliden Rönnskär. Boliden Rönnskär manages supply and demand uncertainty through its relationships with suppliers and customers, and the appropriate location of the materials and information differentiation points, so that most of the objects supplied are sold before they arrive at Boliden's facility in Transvection 5.2. Close interaction and information sharing between the suppliers and customers is an enabler of these processes, which, in case of delivery of copper cathodes to Elektrokoppar, take place via application of the 'just in time' principle.

The printed circuit boards and electronic granules from the used laptops influence the inter-firm relationship between Sims Recycling and Boliden Rönnskär in terms of its continuation in Transvections 5.1 and 5.2. The relationship between these two companies affects the stable supply and distribution of the material so that operations at Boliden Rönnskär can proceed without any costly production downtime. When it comes to transportation, both electronic granules and printed circuit boards are adapted by means of standardised containers and wagons to the requirements of both the logistics service providers and the materials handling facility at Boliden Rönnskär. In this way, Boliden Rönnskär can achieve a seamless flow internally, as well as with respect to the materials differentiation points of a number of metals to customers. Since Boliden Rönnskär has many other customers apart from Elektrokoppar, the Elektrokoppar–Boliden Rönnskär relationship does not affect Boliden as much as vice versa, as copper is the main input object for Elektrokoppar's facilities. Despite this imbalance in the importance of the relationship, Boliden delivers the copper cathodes to Elektrokoppar on a 'just in time' basis so that Elektrokoppar is not forced to hold any inventories before its manufacturing commences.

In Transvections 5.1 and 5.2, copper cathodes have an impact on the organisational relationship between Boliden and Green Cargo, since the volumes transported largely influence efficient resource employment of crossing points, such as the trains and wagons belonging to Green Cargo. Besides the distribution of copper cathodes to Elektrokoppar, Boliden Rönnskär contributes to the maximisation of fill rates of the crossing points in the form of wagons returning to Boliden with the electronic scrap and mined concentrate from Sweden and the rest of the world. From Boliden's perspective, Green Cargo arranges timely and cost-efficient means of transportation to Elektrokoppar, which strengthens the business relationship in terms of resource ties between Elektrokoppar and Boliden Rönnskär.

The object's interfaces with organisational relationships in Transvections 5.3–5.5

Used and/or refurbished laptops influence the relationships between Atea Logistics and brokers such as Once Again and Inrego. Once Again, Inrego, and other brokers provide information about features currently requested by their customers. Information on the conditions of supply and demand of objects, which is exchanged in organisational relationships via classification, information, and planning systems between disposers and Atea Logistics; Jemacon Logistics and Atea Logistics; and Atea Logistics and brokers, facilitate refurbishing in line with the principles of postponement and speculation in Transvections 5.4 and 5.5. In this way, inter-firm cooperation within relationships affects the appropriate temporal organisation of object and information flows between disposers and secondary end users.

The relationship between Atea Logistics and Jemacon Logistics in Transvections 5.4 and 5.5 is significantly influenced by used laptops and other IT equipment. Atea Logistics and Jemacon Logistics specialise in logistics and work together to plan the routing of used IT products from disposers to Atea Logistics' refurbishing facility in Växjö. Thus, used objects have an impact on the relationship between disposers and the logistics service providers – Atea Logistics and Jemacon Logistics – since these relationships facilitate information exchange about object features related to forward and reverse physical flows in Transvections 5.4 and 5.5.

As Atea Logistics is a major customer of logistics services provided by Posten, this relationship has an impact on Posten with respect to a certain reserved capacity assigned to Atea Logistics. Nevertheless, Posten has many other relationships of various types, which means that it is not as affected by the relationship between Atea Logistics and Posten as vice versa. In terms of volumes transported, Schenker and Atea Logistics do not exert any great influence on each other, since they each have other partners that are more important.

To summarise the analysis of the resource layer, there are higher tensions in recycling resource constellations than in those ones related to refurbishing and remanufacturing. This is caused by the fact that refurbishing requires similar resources to those in forward physical flows. Recycled and remanufactured objects can be in competition with virgin raw materials and new products. At the same time, both recovered and new objects can jointly utilise the same resources, as is the case in synchronised collection of used objects and delivery of new ones. New accessories can be combined with the reverse physical flows of refurbished products so that they share the same resources. Recycled materials can complement the mined concentrate in the overall demand for raw materials and in resource utilisation during their manufacturing. In addition, business relationships between actors influence efficiency in resource combining and recombining. Thus, in the next section, resource combining and activity coordination are scrutinised through the actor layer of the ARA model.

5.3 Analysis of organising product recovery in the web of actors

This section aims to examine the actor network surrounding Atea Logistics, which is presented in Figure 5.9. Analytical concepts that are associated with the actor layer of the ARA model are used in order to discuss business relationships in this network.

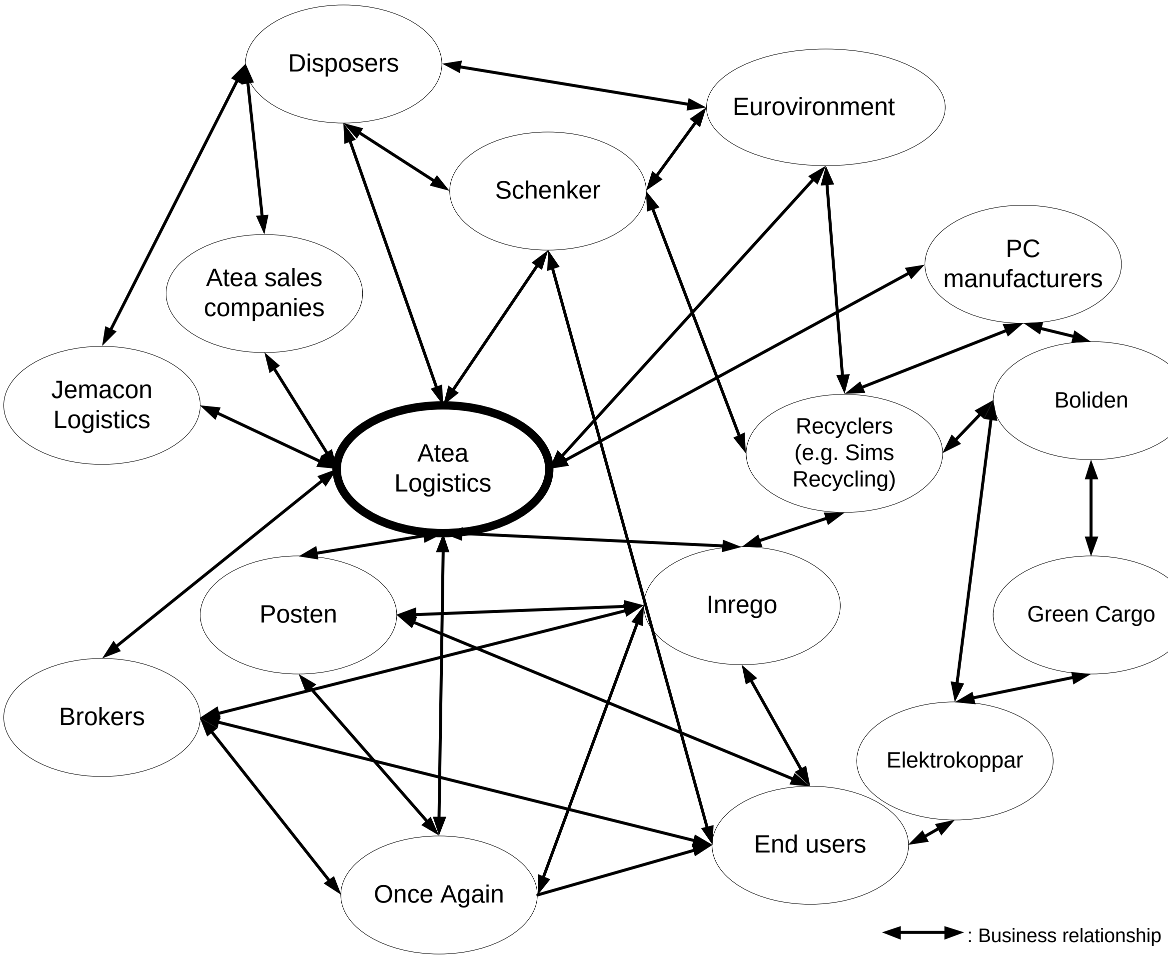


Figure 5.9 Business relationships in the network surrounding Atea Logistics.

Analysis of the actor layer of this network begins with a discussion of the nature of business relationships and the positioning of actors. The second and final part of this analysis scrutinises information sharing and classification in the network.

5.3.1 The nature of business relationships and the positioning of actors

Close collaboration in the business relationship between Eurovironment and Atea Logistics has made it possible to achieve flexibility in activity coordination and resource combining of collection and reprocessing operations. Furthermore, continuous adjustments in the activity and resource dimensions of networks have led to the development of classification systems, which direct the objects based on their classifications into different product recovery options, as efficiently and as effectively as possible. In other words, this relationship has served as an enabler of actors' specialisation and positioning in a counterpart-specific way according to object classes, and/or the objects' input and output values. These classes reflect the resource collection and activity structure of each firm. For instance, Eurovironment and Atea Logistics have positioned themselves towards each other through resource adaptations by linking classification, enterprise planning, article/order, and database systems.

However, the presence of extended inter-organisational communication channels creates some delays and disruptions in the cooperative coordination of activities and resource combining between Atea Logistics and Eurovironment. All orders received by Eurovironment come through Atea Logistics (on occasion with incomplete information), and never directly from the sales companies of Atea Group. This may result from Atea Group's competitive policy towards its internal and external suppliers of products and services. This means that sales companies can choose to procure product recovery services from other suppliers, in addition to Atea Logistics. Therefore, in order to maintain its position, Atea Logistics fosters its direct relationship with Atea's sales companies, which represent the link between Atea Logistics and disposers. Otherwise, sales companies or disposers themselves could choose Eurovironment as their supplier of logistics and product recovery services, due to Atea Group's competitive policy that allows the sales companies to select external suppliers of these services. In this regard, Atea's policy that permits its sales companies to enjoy relatively extensive freedom in choosing their suppliers of product recovery services can disturb the development of resource adaptations, and limit the formation of a closer relationship between Atea Logistics and Eurovironment. This fact does not benefit development of the strategy of close collaboration and extensive interaction.

In addition to mutual adaptations of classification systems for route and enterprise planning between Atea Logistics and Eurovironment, both parties have agreed upon boundaries regarding features of objects. More precisely, the boundaries between these two actors concern sorting and transformation rules on what objects to assign to resources for transformation at Atea Logistics. In this way, boundaries generated by the inter-organisational classification system with respect to differences in the type of objects that are handled by Atea Logistics and Eurovironment accommodate cooperation between these firms. An additional advantage of these boundaries is the establishment of stability in the relationship. This stability can be used to generate improvements in activity coordination and resource combining through actor specialisation.

Along with the accommodation of collaboration in joint provision of the product recovery services to the disposers, boundary setting decreases the risk of direct competition between Eurovironment and Atea Logistics, as both parties have relationships with the disposers. Without classified boundaries with regard to the objects belonging to various identities of disposers, the collaboration would not be viable. Nevertheless, the fact that Eurovironment is cooperating with other disposers is benefiting Atea Logistics, since Eurovironment can spread the fixed costs of investments over several units. This is attributed to joint resource and capacity utilisation. On the other hand, both companies compete in refurbishing as they are allowed to sell to whomever they wish – whether intermediaries or end users. This inter-firm competition between Atea Logistics and Eurovironment is therefore an outcome of the similar requirements of their buyers of refurbished products. On this side of the network, Atea Logistics and Eurovironment apply a mixture of high- and low-involvement approaches to business relationships, while focusing on internal efficiency.

Relationships and positioning in Transvections 5.1 and 5.2

An example of positioning in terms of simultaneous competition and cooperation on the national level in the product recovery networks, such as those in Transvections 5.1 and 5.2, is the creation of an association of recyclers. On the national level in Sweden, recycling companies such as Stena Metall, Sims Recycling, and Kuusakoski are more directly affected by the WEEE Directive than other actors who perform refurbishing, remanufacturing, and repair. To communicate their point of view on the changes of rules and collection rates to the regulators – that is, municipalities and the Swedish Environmental Protection – and to distribute the rules of directives on hazardous, electronic and electrical waste to their members, the competing recyclers have established the Swedish Recycling Industries' Association.

When it comes to positioning in terms of simultaneous competition and cooperation, there are links between actors in the product recovery and forward supply and production–distribution networks. Apart from receiving electronic scrap from the end users, Boliden Rönnskär receives production waste from the electronic manufacturers via Sims Recycling. Sims Recycling helps the producers to dispose of and recycle their waste, while at the same time selling refurbished products and thus competing with the manufacturers of new products.

A more high-involvement approach to the relationship strategy of simultaneous competition and cooperation is adopted in the case of competition regarding refurbished objects between Sims Recycling and Atea Logistics (and other refurbishers), since Sims Recycling receives a continuous stream of electronic waste from Atea Logistics via Eurovironment from Transvections 5.1 and 5.2.

When it comes to recycling in Transvections 5.1 and 5.2, it is the classification system of Eurovironment and Atea Logistics and its sorting rules that determine what output with its reference values should be sent to Sims Recycling. Sims Recycling has positioned its activity structure and resource collection with regard to inputs to its facilities and processes, as well as outputs that are adapted to various counterparts' resources and activities. For example, in Transvection 5.1, a used laptop with classified properties that are not in demand is transported by Schenker to the facilities for shredding and dismantling, so that two main classes of objects are sent to Boliden Rönnskär for the production of raw materials: the pre-shredded printed circuit boards and electronic granules. These outputs are adapted for efficient activity coordination and resource combining by the facilities at Boliden Rönnskär, at the same time as they determine the boundaries between these two actors. The same boundaries generated by the classification system are applied to two other Swedish recyclers, Stena Metall and Kuusakoski, who supply electronic scrap to Boliden Rönnskär. The positioning of Boliden Rönnskär is determined by its production facilities and processes, as well as by the inputs and outputs with regard to its business partners on the supply and demand side. Apart from selling products to Elektrokoppar and other customers, who are not in direct competition with Boliden Rönnskär, Boliden sells certain waste and by-products to the actors who might be competitors with regard to other outputs of their facilities and processes. These competitors also supply Boliden Rönnskär with what they regard as waste and by-products. The classification systems with sorting rules with regard to waste and by-products are enablers of cooperation, even among very similar competing firms.

Boliden Rönnskär mostly uses the high-involvement strategy on the supply and demand side of the company with regard to objects to be recycled, as well as with respect to logistics service providers. For instance, each new supplier is given a three-year trial period so that the relationship can evolve by means of activity adjustments and resource adaptations. The number of inspections of the sampling results used to determine the monetary value of the supplied shipments tends to decline as the business relationships and trust develop.

However, Boliden Rönnskär tweaks its positioning and purchasing behaviour (as do the rest of the smelters) with regard to electronic waste during periods of economic growth and surplus supply, since it then implements the terms of supply and procurement that are more advantageous to it. On the other hand, in order to sustain continuity of the physical flows and operations, the importance of long-term perspective in stable business relationships with regard to its suppliers is advocated during the periods of economic recessions when there is a lack of the supplied electronic scrap. In order to avoid situations of potential conflict and abuse of advantageous circumstances on both the supply and demand side, Boliden Rönnskär and its suppliers could systematically adjust their operations through information exchange and more reliable forecasts in order to secure continuity of operations over a longer period of time. Although information-gathering on future supply through the recyclers associations on the European and national level is already taking place, there seems to be a greater need for information exchange regarding the expected volumes. Nevertheless, since production downtime and insufficient capacity utilisation cost a great deal at Boliden Rönnskär, the company has established relationships with recyclers in North and South America, who can step in whenever European recyclers fail to deliver the demanded supply of electronic scrap.

The high-involvement strategy of extensive interaction and close collaboration by means of the structuring of suppliers in fixed tiers in order to prevent direct price competition and promote cooperation has created strong activity links, resource ties, and actor bonds in Boliden Rönnskär's supply network. In addition, this reduces the transaction costs associated with the internal management and administration of a larger number of suppliers. The classification system is an enabler of this structure, as it transmits information on what object classes Boliden and its suppliers may receive as inputs in order to generate appropriate and efficient crossing and differentiation points.

On the demand side, the high-involvement strategy is reflected in the ‘just in time’ deliveries to Elektrokoppar. This strategy has enabled Boliden Rönnskär, Green Cargo, and Elektrokoppar to synchronise their activities and adapt their resources. Depending on, among other things, the rules of Incoterms, the actors regulate the responsibility for transformations in place and time.

As of 2013, the electronic scrap containing rare earth metals has not been supplied in adequate amounts to be processed in a scale-efficient way. Instead, it is being sent to landfill. According to Boliden Rönnskär, this has been caused by the recyclers’ unwillingness or inability to store these objects or generate sufficient crossing points and send them in amounts that can be processed by taking advantage of the economies of scale offered by Boliden’s machinery. Whether this is due to a lack of communication between Boliden Rönnskär and their suppliers of electronic scrap or inappropriate rules of the WEEE Directive is a matter that can be investigated. When it comes to the WEEE Directive, a relevant question that deserves attention is whether overly detailed rules of the directive reduce the possibilities to succeed in efficient recycling of rare earth metals.

Relationships and positioning in Transvections 5.3–5.5

In contrast, as Eurovironment, in its role as a potential direct competitor, is not involved in the coordination of physical flows in LOOP 4 (that is, Transvections 5.4 and 5.5), there is greater openness and information sharing between actors involved in this business setting. Atea Logistics’ main collection partner, Jemacon Logistics, is a more specialised logistics service provider that is not as focused on distributing and remanufacturing used objects as Eurovironment. Thus, the risk of direct competition of these classes of objects between Atea Logistics and Jemacon Logistics is smaller than with Eurovironment. This relationship exhibits all of the characteristics of a high-involvement approach to business relationships. Business relationships characterised by these kinds of high-involvement features usually promote efficient and effective activity coordination and resource combining. Therefore, in Transvections 5.4 and 5.5, the disposers, Atea Logistics, and Jemacon Logistics have tried to take advantage of the spatial proximity of the disposing organisations in joint logistics planning. Through resource adaptations in LOOP 4, actors try to increase the efficiency of the resource constellation of the network. In this manner, organisations have created activity links and resource ties with the aim of cultivating and advancing activity adjustments and resource adaptations. This increases capacity utilisation and enhances efficient resource combining as the actors involved in Transvections 5.4 and 5.5 always try to achieve full truckloads in transportation.

With regard to logistics service providers, such as Jemacon Logistics, Schenker, and Posten, there are economies of scale when forward, reverse, and/or back-haul physical flows are coordinated. To be more precise, objects can jointly utilise distribution resources of crossing points, such as pallets, containers, trucks, and hubs with respect to many consignors and consignees. Through the utilisation of standardised pallets, Atea Logistics, Inrego, and Once Again have all made adjustments in relation to resource collections by Posten and Schenker. In Transvections 5.1 and 5.2, Eurovironment, Sims Recycling, and Boliden Rönnskär made similar adaptations vis-à-vis Schenker's standardised containers that transport electronic scrap. These two large logistics firms have developed resource structures with a focus on these standardised pallets and containers. The network surrounding Schenker and Posten displays a blend of high- and low-involvement strategies, with standardised interfaces and various levels of relationship involvement with the consignors and consignees.

Concerning cooperative positioning between logistics service providers, it is evident that firms that are procuring transportation of goods create boundaries associated with national borders. For example, Atea Logistics employs Posten for Swedish deliveries and Schenker for Norwegian and Danish deliveries, irrespective of the content of shipments in Transvection 5.4.

From the perspective of logistics service providers, it is also apparent that they position themselves with regard to senders and receivers through differentiated resource combining and activity configurations. The most notable difference in resource collections and activity structures is between Jemacon Logistics, and Posten or Schenker. While Jemacon Logistics has created a resource combination that is adjusted for the logistics of IT equipment, Posten and Schenker adapt the products in relation to their resource structures for palletised consignments. In other words, as resource adaptations in the business relationship between Jemacon Logistics, disposers, and Atea Logistics are more actor-specific, they require more intense interaction, which is typical of the high-involvement strategy. Actor positioning through specialised load carriers provided by Jemacon Logistics improves activity coordination, since this equipment is adapted in relation to facilities belonging to disposers, reprocessors, and distributors.

Differentiated positioning between actors in forward and reverse physical flows is evident in the relationship between Atea Logistics and PC manufacturers. Since Atea Logistics now only sells logistics services and does not make a profit on new products, the company has ended up in a less favourable position in its relationships with PC manufacturers, who have therefore bypassed Atea Logistics in their sales of new products. When it comes to reverse distribution, Atea Logistics is able to make a profit with regard to products and services. Furthermore, Atea Logistics and manufacturers cooperate in the coordination of activities and resource combining involved in product recovery configurations. By distributing refurbished products, Atea Logistics is indirectly competing with PC manufacturers, as the refurbished products can end up with end users that do not desire to replace their old equipment. This situation is usually avoided, as most products are transferred to end users in other geographical regions. From a wider network perspective, it seems that Atea Logistics has gained a more advantageous position in and through the business relationships involved in product recovery contexts, as brokers occasionally bid against each other in order to obtain refurbished products from Atea Logistics. Thus, by adopting a high-involvement strategy on the supply side of the network, Atea Logistics is able to implement a more low-involvement approach on the demand side with regard to remanufactured objects.

In terms of business relationships with brokers of refurbished equipment, Atea Logistics normally sells these products to distributors, such as Inrego and Once Again, in Transvections 5.3 and 5.5. These brokers handle a large number of relationships with a varying level of interaction, in order to leverage supply and demand. Thus, business relationships with buyers, sellers, and intermediaries enable brokers to search for products throughout the network. In a similar vein, Inrego's and Atea Logistics' relationships, which are not characterised by intense interaction and close collaboration, are important in finding a match between supply and demand. Both of these brokers could potentially be in direct competition with Atea Logistics, because they perform refurbishing activities and combine resources on products that come from disposers via Jemacon Logistics. Yet again, it is crucial to create boundaries through the classification systems and rules for sorting of object classes in order to promote cooperation and avoid direct competition in relationships that display regular interaction patterns of high-involvement strategy (for example, when Atea Logistics sells refurbished units to Inrego), and in situations characterised by more irregular interaction processes when a low-involvement strategy is applied (such as when Atea Logistics buys from Inrego or when Inrego distributes its refurbished products).

5.3.2 Information sharing and classification in the network

Regarding Transvections 5.1–5.3, the management of activity interdependencies between Schenker, brokers, Eurovironment, and Atea Logistics is supported by actor-adapted information sharing. The fact that disposers determine whether, when, and where the objects enter the network on a short time basis imposes uncertainty in the form dimension from the perspective of Eurovironment. This uncertainty is translated into time and space uniformities of objects, as their physical characteristics need to be determined at Eurovironment's facility. Objects that are diverse in terms of their material content or product features are collected from disposers at the same time and place, with the aim of obtaining economies of scale in transportation. At Eurovironment, classification in the form dimension steers the objects into facilities that specialise in different product recovery options (that is, to Atea Logistics for refurbishing and/or to Eurovironment for recycling).

At Eurovironment, Inrego, and Atea Logistics, the software used and the sorting put into effect is closely related to the prototype classification system. That is to say, the system uses already-stored object classes with their reference values in order to classify them for further distribution to a new end user, or to a recycling firm. Recycling firms use the classification system based on a predetermined number of classes as in Aristotelian classification in order to distinguish one object from another and thus establish inter-organisational boundaries. This is caused by the fact that the objects at the information differentiation points have to be described more firmly.

Thanks to close collaboration between Schenker and Eurovironment, it is possible to achieve economies of scale and efficient routing during the collection of used objects. One of the reasons for this effective activity coordination is the intensive interaction between Eurovironment and disposers. However, this interaction and information exchange was, as of 2012, limited to the place and time dimensions of used objects, as Eurovironment did not exert any influence on the disposers' choice of LOOPs. The topological approach to classification systems, in which additional classes related to the form dimension are induced, would have improved the quality, quantity and accuracy of information in this respect, since a larger amount of accurate data would have been collected. This could have enabled greater and better informed decision making.

Since Atea Logistics receives a huge share of non-functional units via LOOP 2 (Transvection 5.2) and LOOP 3 (Transvection 5.3), which it must send back to Eurovironment, it is crucial to continuously adapt and adjust sorting rules that direct objects between the facilities of Eurovironment and Atea Logistics. Thus, joint adjustment of activities and transfer of sorting and grading rules between actors in the network may decrease excessive transportation and storage.

Further down the network, standardisation of rules and classifications of refurbished objects between Atea Logistics and second-hand brokers provides a reduction in uncertainty with regard to monetary value and quality. Linking of product characteristics and price through the grading of refurbished objects reduces uncertainty in the network because it creates a common language. This is aided by the prototype classification system, which decreases the need to test, classify and grade products at each step in the network.

There is a similar type of social contract in Transvections 5.1 and 5.2, as recyclers (such as Sims Recycling) and smelters use a grading system related to the weight of gold in grams per tonne of electronic waste to price each shipment of electronic scrap. The identity of the object and the class of product determine this grading, as low-priced brands of used laptops contain less gold than high-priced ones. Furthermore, the class of the products out of which printed circuit products are taken has an influence on the price of each consignment sent to Boliden

Rönnskär, since, for example, the printed circuit boards of computers have a smaller amount of gold compared to the server stations.

The network surrounding Boliden Rönnskär with regard to electronic scrap displays the features of a more high-involvement strategy compared to the network related to the supply and production–distribution network of the virgin raw materials. Owing to the fact that there is a greater diversity and uncertainty in form of the supplied printed circuit boards than in the ore, this network is more organised and the volumes exchanged are regulated on a yearly basis, compared to the higher quantity flexibility in the supplied mined concentrate and demanded virgin raw materials.

Thanks to adapted information-sharing between the suppliers, and production, purchasing, and sales departments concerning form, quantity, time, identity, and place features, Boliden Rönnskär is able to sell most of its products before they arrive at Boliden's facilities. The company has a number of reference values in terms of monthly and annual production rates and inventory levels, which are described in tonnes and prices of particular object classes and provided to suppliers and customers in order to sustain continuity of supply and demand and to avoid production downtime. In turn, suppliers and customers transmit information regarding changes in the values of object classes and the classes themselves demanded and supplied so that Boliden Rönnskär can adapt its plans. By placing the information differentiation point as far upstream as possible in the network, diversity and uniformity are balanced as the objects at the materials differentiation points can be managed by taking advantage of economies of scale in object differentiation towards the customers of the raw materials. In addition, as the safety stock is substituted by information, the overall costs of the network are reduced.

Besides having their own firm-, relationship-, or industry-specific classification, and information systems in terms of enterprise and materials-planning systems, and order and article number systems, the actors fit themselves into the web of actors by means of more abstract or general classification, measurement, and rule systems, such as the International System of Units, price system, Incoterms, and The Periodic Table of Elements. As the object classes and/or their values change when they are sorted and transformed in the network, so too does the quality and quantity of information, experience modifications. That is, information content has to be adapted to each actor's need to coordinate activities and combine resources.

Tightly and loosely coupled classes are associated with the longevity of the object classes. The most persistent characteristics of products such as laptops are various raw materials and the energy that went into its production, which are extracted during recycling and incineration. Remanufacturing, repair, and refurbishing are characterised by more loosely coupled classes, as the values of their object classes can easily be replaced by the instalment of parts with alternative values.

In summary, positioning of actors is achieved through interaction in business relationships. In order to match supply and demand it is crucial to have a mixture of high- and low-involvement relationships. Business relationships are thus important for efforts related to specialisation and setting of boundaries in the activity and resource layers of networks by means of classification systems, so that direct competition is avoided. Sorting rules, which are part of the classification systems, direct the objects in the resource constellations and activity patterns. The establishment of various kinds of classification principles and classes of inputs and outputs between the actors reflect the resource collection and the activity structure of each organisation in the network. Information exchange has to be adapted to each actor's needs so that the actor can efficiently operate its activities and resources. Hence, one of the functions of a transvectional chain in terms of information flow is to sort and transform information between the firms. Both Aristotelian and prototype-based classification systems transmit information on which object classes are supplied and demanded.

5.4 Summary of the case analysis

Transvections 5.1–5.4 in the network around Atea Logistics operate according to the principle of speculation, in order to exploit activity similarities. This is the result of used products being sent from disposers more or less autonomously with respect to issues such as quantity, quality and time. Logistics service providers coordinate activities in terms of quantities that can be collected during a visit, and lead time for pick-up orders.

Transvection 5.5 is organised according to the principle of postponement. The exchange of accurate and adapted information facilitates efficient scheduling of simultaneous delivery of new products and collection of used ones. In this way, it is possible to handle parallel and sequential dependence of activities between disposers and end users of refurbished and recycled products in an organised way.

Business partnerships in the network into which Transvection 5.2 is embedded have led to the development of actor-adjusted exchange of information regarding the objects' time, form, place, identity, and quantity features between the recyclers, Boliden Rönnskär and Elektrokoppar. High-involvement relationships have resulted in the effective management of supply of electronic scrap and demand uncertainty of the raw materials, and efficient localisation of crossing and differentiation points. The outcome of this relationship strategy is that most of the objects to be processed by Boliden are sold prior to their entry to the company's facilities, and delivered to Elektrokoppar via implementation of the 'just in time' principle.

In Transvection 5.5, many objects coming from disposers share the same features. This enables reduction of uncertainty with regard to time, place, identity, and form dimensions of individual objects for Atea Logistics and other actors. Because information exchange via classification systems takes place prior to physical handling, Atea Logistics can start promoting objects even though some might not be working, following inspection at Atea Logistics. In other words, even if an object does not meet the requirements (due to defects, for example) of new buyers, other, similar objects can replace the malfunctioning ones. Thus, by exploiting parallel dependencies between activities, Atea Logistics utilises business relationships to search for buyers of particular objects in use at the disposer.

Organisations involved in product recovery arrangements are concerned with resource combining and recombining during collection, reprocessing, and redistribution. Object features are changed during the object's interaction with facilities, organisational units, and organisational relationships. There are tensions and adaptations in product recovery resource constellations. Tensions are visible in recycling arrangements, since the objects are mostly adapted to forward physical flows. From the perspective of remanufacturing, there are competitive tensions between new and used products offered to the same end users. Adaptations are present in remanufacturing, where objects are easy to disassemble since they were designed for efficient assembly in forward supply networks. Moreover, both used and new objects can share the same resources in transportation, reprocessing, and redistribution.

The nature of business relationships between actors impacts on the organising of product recovery arrangements, in terms of how activities are coordinated and how resources are combined. Interaction between organisations facilitates cooperative boundary-setting between specialised actors by means of classification systems, with their rules and input/output values (for example, in terms of types of products that are exchanged between companies). In this way, companies can differentiate themselves with respect to the supply and demand of their products and services. These boundaries enhance cooperative efforts among firms regarding resource adaptations, and decrease the risk of direct price competition. This applies to business relationships with varying degrees of interaction intensity or low- and high-involvement approaches.

Finally, established object classes for information handling of objects regarding form, time, place, quantity, and identity, provide an aid for sorting and transforming objects within facilities where different kinds of product recovery operations are performed. Classification systems may be of a more general nature, or network- and firm-specific. Their sorting and transformation rules determine the path of the object and the way in which raw materials, parts, and products are combined and recombined with facilities, organisational relationships, and organisational units. When an order is placed at the information differentiation point, it has to be organised into a fixed number of classes that demarcate the object from others by means of typological and Aristotelian classification.

6 EMPIRICAL FINDINGS RVG

This empirical illustration is primarily concerned with a Swedish regional government, a provider of public healthcare to citizens of RVG, and their arrangement for regular exchange of used computers with new ones. This leasing programme started in 2006, making it one of the first and largest of its kind in Europe, and the first of its kind in Sweden. The focus in this description lies in how a number of companies organise and perform reverse distribution processes. The PCs are provided by Dell according to a three-year lease and warranty contract. The collection and delivery rate of the project is 700–800 PCs per month during all three years of the agreement.

6.1 Introduction

RVG is a county council that is responsible for the health care and sustainable development of Västra Götaland, a region located in Western Sweden. Its mission is to improve the health, culture and economic growth of the region. RVG county council was created via a merger between the county councils of Gothenburg and Bohus, Älvsborg and Skaraborg Counties in 1999. RVG's main responsibilities are for the public transportation and tax-funded health care system.

RVG includes all public governments, corporations, offices and secretariats in the county, which are not part of the political structures. These regional organisations are responsible for ensuring that political decisions are respected and implemented. With regard to its health care mission, RVG provides medical services in dental/health care centres and hospitals. There are 18 hospitals with a large number of specialist clinics, 205 health care centres and 170 dental care centres that serve 1.5 million citizens of the region. Even some private health care clinics have contracts with RVG. Out of a total of 50,000 employees of RVG, 90 per cent work in the health care sector of the regional government.

In the initial phase of the project in 2006, coordinating business units had to gather information on where the units and disposers were located for the sake of efficient route planning, as this information had never been stored before. Moreover, there were (and there remain) different requirements with respect to hardware and software that distinguish administrative and operational activities. The creation of similar, standardised hardware and software specifications for as many employees as possible resulted in economies of scale in administration, logistics and production for RVG, its logistics service providers, and Dell.

Both the specifications and leasing period are determined during a public tender phase. The central purchasing organisation negotiates standard equipment specifications that are going to be used in terms of features such as the processor speed, the size of the monitor, the storage space, laptop or desktop, price, and other product characteristics. Prior to the structuring and storing of information in the initial phase of the project for the regular replacement of computers, it was only possible for RVG to identify the last point in time when somebody logged into the telecommunications network of the organisation. As of 2006, it was possible to track and trace all of the computers in use, and to locate all IP[39] addresses in terms of their room and storey numbers, departmental placement, and user identity.

The employees of RVG use PCs made by Dell in their daily work. Dell is one of the biggest PC manufacturers in the world. It coordinates distribution and provides different services for RVG's IT equipment, in collaboration with RVG's partners. Dell is also involved in research and development activities within the IT sphere. More than 100,000 people worldwide are employed by the corporation.

Every third year, Dell is involved in a public tender concerning the lease and purchase of new IT equipment, and collection of old devices used by the employees of RVG. If a PC manufacturer and its partners have shown satisfactory performance in the delivery of new computers and handling of used computers, then the contract may be extended for two more years. Otherwise, another public tender is declared and other parties are allowed to participate in the process. For instance, distributors of IT products can procure delivery, unwrapping, and other services from different IT companies who have lost their direct agreement with RVG. Thus, even if another firm, such as Dell, secures the deal from RVG or another public organisation, the same actors may continue to perform the same tasks, although the financial flows for products and services may differ. Dell's Swedish sales department works with the purchasing department of RVG during these tenders to determine specifications and delivery plans.

There are a number of advantages associated with the leasing contract between Dell and RVG. An example of these benefits is the fact that RVG does not have to pay large amounts to buy all equipment at once. Another advantage of this arrangement is that the personnel of RVG do not have to handle any products physically, since the used PCs are collected by a logistics service provider, IT Logistic, from RVG's workplace and placed in specially designed rolling load carriers. However, there is still work to be done in ordering, storing information, keeping control over equipment and guiding drivers during the collection of used units. Within the framework of the leasing agreement, RVG's personnel simultaneously order the physical collection of their used PCs and delivery of new ones every third year.

In the following sections, this business setting will be discussed in detail. Table 6.1 shows how the product recovery processes are divided between the organisations, which are

[39] An Internet protocol (IP) address is a tag assigned to each IT product in order to provide the location and interface identification in a computer network.

described in separate sections of this part of the thesis, and the order in which these actors are presented in this chapter.

Organisation	Processes
RVG	Handling of used PCs and disposal orders
Infocare	Logistics management of disposed products
IT Logistic	Provision and coordination of reverse logistics
Igus Data	Reconditioning/remanufacturing
ReuseIT	Distribution of refurbished products
SITA	Collection and classification of waste

Table 6.1 Distribution of processes among actors that are described in separate sections of this chapter.

The starting point of the physical flow for used PCs is the organisational units in the region that utilise PCs in their daily operations. These organisational units are referred to as disposers. A summary is then given of the firms, and their assets involved in the gathering of used equipment, and the transportation, classification of products in regard to different reprocessing alternatives, and recycling. In addition, the way firms distribute and market refurbished products and obsolete materials is described.

6.2 The handling of used computers from RVG

As illustrated in Figure 6.1, several companies cooperate in the planning and logistics of collection of the used PCs and the distribution of new equipment to various operational areas and functions within the regional government. For project coordination, Dell works closely with Infocare, a firm that specialises in the management of integrated forward and reverse physical flows in pre-planned replacement programmes. Infocare is also responsible for the warranty service of hardware for RVG. Another firm involved in the regular exchange set-up together with Infocare is IT Logistic, a specialist in transportation and inventory holding of new and used products. IT Logistic, in its turn, forwards PCs to Igus Data and ReuseIT, which are experts in remanufacturing and distributing second-hand products to new buyers. SITA Sweden (hereafter SITA) collects and classifies electronic and electrical waste from the refurbishing facility of Igus Data and ships it to Kuusakoski, which recycles the classified waste.

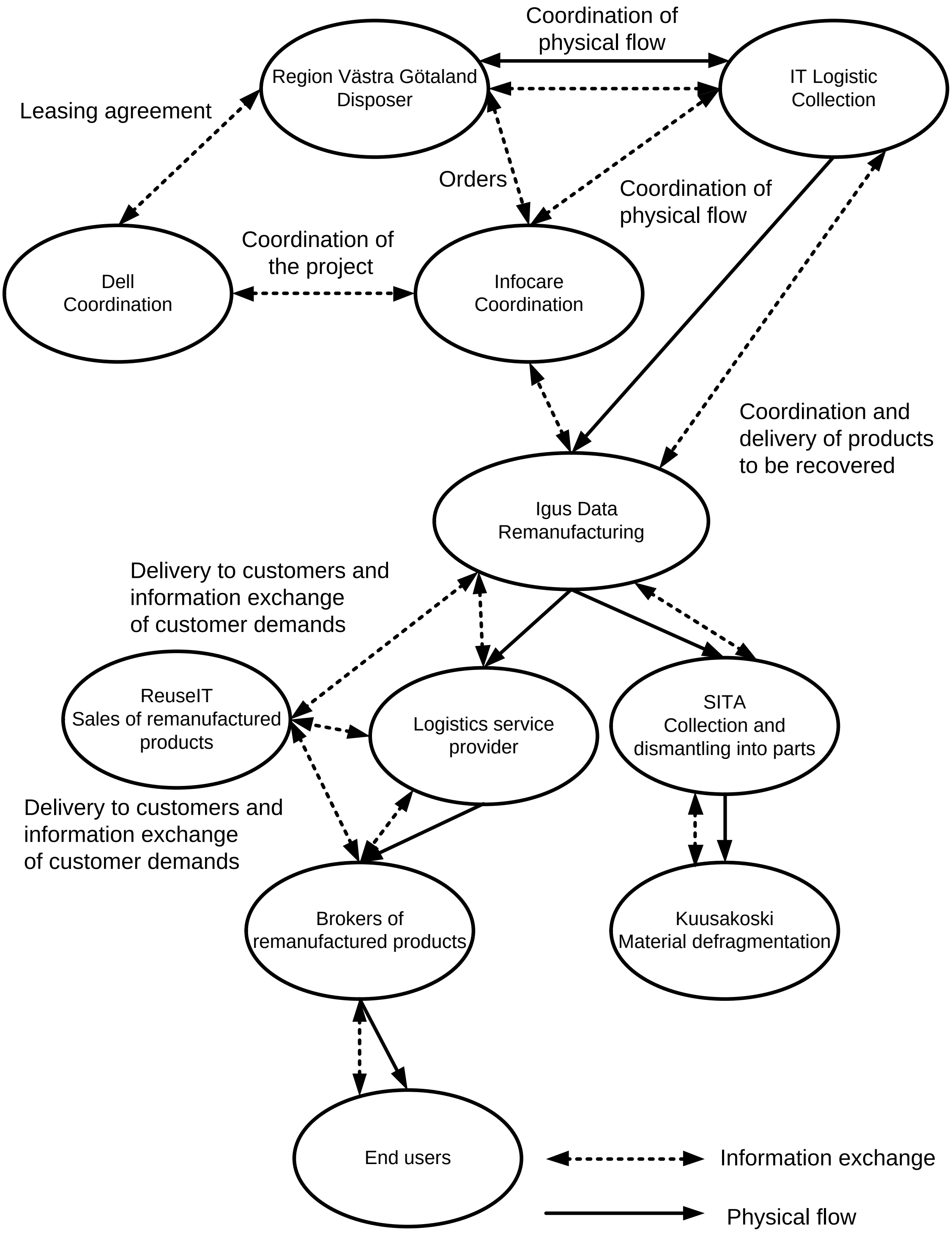


Figure 6.1 Actors involved in product recovery of RVG's obsolete IT products.

The crucial factor for the success of the project was the collection of information and strategic long-term planning between RVG and Dell. This information-sharing makes both of these actors aware, several months in advance, of when and where used PCs are to be replaced by new ones. This creates opportunities to make both the production and delivery of new PCs, as well as the gathering of old ones, more efficient than when this was done more on a case-by-case basis. A great deal of team cooperation is required from RVG's side to coordinate this arrangement. The sales department of Dell, the purchasing and IT service departments of RVG, and the project sales department of Infocare are directly involved in the negotiation. IT Logistic, ReuseIT and Igus Data do not have any extensive direct contact with either Dell or the users of the new equipment during strategic negotiations between Dell and RVG, as this type of information is administered by Infocare.

The job of organising, information sharing, setting up rules and useful interfaces, deliveries, software installations, and optimisation of time and routes is carried out by various organisational units, as depicted in Figure 6.2. These actors include Infocare, RVG's IT department and IT purchasing council, local departments, regional managers and staff from IT Logistic. All of these business units may be regarded as the coordinating body of the project. Sharing and appropriate structuring of information between different business units in the network is central for the proper operation of the physical flow.

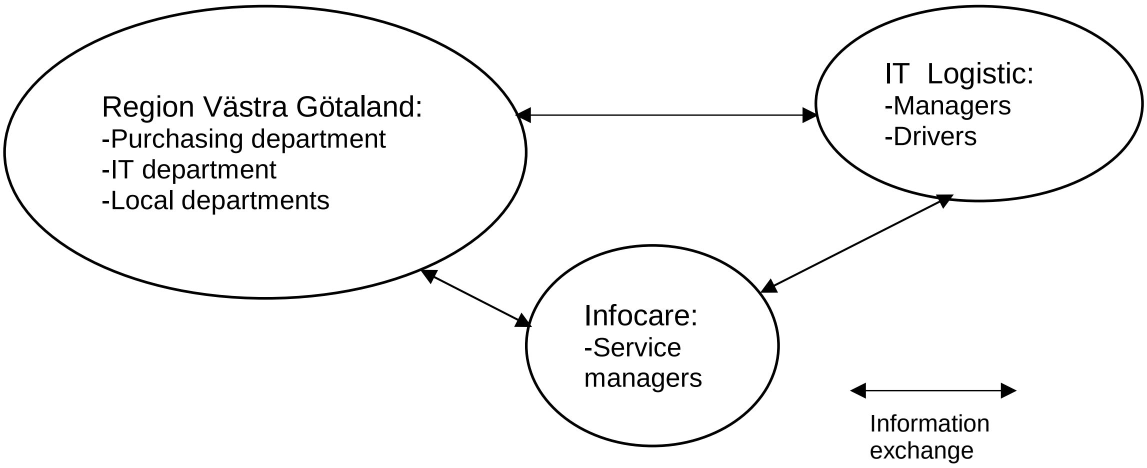


Figure 6.2 Coordination of collection of used PCs from RVG.

Since the start of the project for the regular replacement of IT equipment, the coordinating business units have made adjustments between parties, such as increasing the time period in terms of months between order placement and the point in time at which the used PCs are collected. This allows more time for the efficient geographical planning of consolidation in terms of loading rates and geographical proximity between various disposers of the equipment in the same and/or different organisational units during a single day. The orders sent to Dell's sales representatives by the disposers are also sent to other cooperating firms for the planning of production and transportation of new products, and collection and reconditioning of used units.

6.3 The handling of orders for disposal by RVG

Order placement within RVG's organisational units is geographically spread across different cities and towns within the region. Each month, a consolidated order is handed over to Dell and Infocare, which in its turn transfers the order to IT Logistic, ReuseIT and Igus Data for the planning stage. Accumulation of orders from each employee leads to lower administration costs for RVG. At the same time as RVG personnel order new products, the accumulated order for collection of the used equipment is automatically transmitted to the logistics service provider, which is responsible for transporting the used products to a reconditioning facility. Employees at RVG have a predetermined choice of new equipment packages that are matched to the current specifications of the three-year-old computer in use. Some organisational units decide to keep the equipment for five years, and these are usually collected for material recycling at the firms working with materials shredding and classification, through IT Logistic.

The locally responsible person for IT equipment at an organisational unit makes sure that the placement of the computers is correct by checking the serial numbers, room numbers and names of primary end users. This person usually has other roles in the organisation as well. Through the business system, the person responsible for IT equipment obtains information on which computers should be replaced as they reach three years of age. This has to be done several days before an employee of that organisational unit orders the collection of used equipment and delivery of the new products. The information is presented on an order list, or form, separated into columns with a set of order placement dates, the location of the used units, the names of the departments and personnel, and technical information about the new and used IT equipment. Each order is normally separated into sub-orders of four 'IT box' load carriers (see Figure 6.3) filled with 15–18 computers, which are normally distributed during a single day by a single driver.

Figure 6.3 'IT box' load carrier.

The orders from employees are sent to an exchange coordinator, who works on a more regional basis in terms of gathering orders from several organisations or cities. The number of computers that an exchange coordinator handles depends on the amount of orders for these products, and thus the amount of administration that needs to be managed. The exchange coordinator controls information about the placement of the computers, and provides feedback to the locally responsible person if there are some unclear issues or if there are specifications that are missing in the orders.

When the central purchasing administration of RVG receives the orders from the exchange coordinators, they terminate the leasing agreement for the used units and enter into an agreement with Dell concerning the leasing of the new computers. Thereafter, the order is automatically stored. When the order is sent to Dell, Infocare, Igus Data, and IT Logistic, these firms plan their production, collection and distribution, and send the order receipt back for confirmation. This order confirmation, which is sent through the exchange coordinators and local management, includes data such as the names of the individual disposers, collection dates, addresses, serial numbers and a number of technical details. The purchasing department receives the list with a route plan for the collection of used equipment from Infocare. This firm's collaboration with RVG is described in the next section.

6.4 The management of logistics and product recovery by Infocare

Infocare is an independent Nordic provider of IT-related services to business customers on behalf of PC manufacturers and other large companies. These services include the repair and collection of consumer returns, erroneous equipment, and other malfunctioning electronic parts and products. Infocare's vast distribution network enables them to coordinate geographical and temporal consolidations from several business users of IT equipment.

Infocare was established at the beginning of the 1980s (i.e. at the beginning of the information technology/digital age). Infocare's mission is to maintain a high functionality of the equipment, with as few disturbances as possible to the business. The company offers both customer-adapted and standardised solutions, which are particularly suitable for geographically dispersed organisations, within both the public and private sphere. As a brand-independent service provider, the total offering of Infocare covers the entire life cycle of IT equipment, including purchasing and logistics planning, configuration, handling of the used equipment, refurbishing, and recycling. All of these services are provided in partnership with firms that are storing, transporting, repairing, refurbishing and recycling parts and products.

With 2200 employees, 76 inventory/repair centres, and eight modern workshops for complex technical overhaul, Infocare offers a warranty repair service that is successful after a first onsite visit in more than 90 per cent of cases. Depending on their agreements with business customers and disposers, Infocare employees can repair the IT equipment on the spot. Otherwise, the equipment is collected by Infocare's service personnel and transferred to the repair centres, which are located in proximity to cities and towns in Sweden – that is, where the disposers are located. The repair location depends on the contract terms, circumstances and availability of parts, and the type of malfunction. This is normally offered to large companies and public service providers. In accordance with the agreed conditions, Infocare either brings the parts and tools to the disposer's site, or collects the product from the end users and transports it to the repair centre, where the parts are replaced. It is also possible to reinstall the software through the software interfaces and servers.

6.4.1 Warranty repair services on behalf of RVG

Infocare is the party that replaces malfunctioning components and modules within the relationship with RVG and Dell, as the IT department of RVG repairs software errors. Then, at Infocare's local service centre in Gothenburg, the routes for parts replacement to and between RVG's hospitals and clinics are planned. According to the agreement between Dell and Infocare, parts should be replaced one day after the malfunctioning unit has been reported to Dell's customer service department.

Hence, whenever there is a problem with a product, a technician or an employee at RVG orders the repair service. The first contact is via phone to Dell's customer service in

Stockholm, which initiates identification of defects. By providing the article number to the customer service representative, it is possible to identify the specifications and model name of the computer that should be repaired. As soon as the article number is typed into the information system, the customer service department can provide advice and suggestions for solutions. The representative then asks questions about the issues faced by the particular employee at RVG. This interaction enables the staff within the customer service department to determine the type of part that needs to be ordered and delivered.

Thereafter, the customer service department sends the order to the spare parts inventory in Stockholm, which must receive the order before 5 pm in order to be able to pick the right parts and send them to Infocare's repair service workshop in Gothenburg overnight. Simultaneously, information about the location, delivery time and receiver of the part is transmitted to Infocare. Dell provides the most frequently needed parts via its spare parts inventory. Coordination of transport to Gothenburg is managed by Dell, which tries to consolidate shipments of parts and modules to several organisations within the same region.

Infocare plans the routes for the following day in Gothenburg and its vicinity, as malfunctioning computers appear at a range of different locations within RVG and other organisations in the region on a day-to-day basis. Logistics coordination of parts, and therefore of service personnel from the repair centre in Gothenburg, to the end user's site is managed to minimise transportation distances. Moreover, route planners have to consider certifications in their organisation of spare parts logistics, as many technicians are certified to repair of a certain number of product models.

When certified technicians are on their way to perform repair services, they telephone the relevant organisational units within RVG, where malfunctioning units are located, to confirm their arrival. After arrival, technicians control the model name and article number in order to start testing the product using a specialised software application. In addition, Dell may send several different parts in case customer service employees are unsure about which component needs to be replaced. Technicians disassemble products in order to replace the part. Thereafter, a final test is performed before the next site is visited. If the unit is in working order, the repair personnel send digital confirmation about the failure, customer, repair duration, and article number to Dell. An information system is utilised to connect Dell and technicians on the spot. Malfunctioning components are collected to the repair service centre in Gothenburg. Equipment that is not repairable is shipped to a recycling firm, as soon as a dedicated load carrier for such components in the service centre is fully loaded. The potentially recoverable used parts from RVG are sent back to Dell, and distributed to a partnering refurbishing company. The following section will illustrate the role of Infocare in the handling of used and refurbished products, originally manufactured by Dell, that are disposed of every third year.

6.4.2 Coordination of the integration of forward and reverse distribution

Infocare initiated development of the programme for regular replacement of the computers used by RVG. The company buys used computers from Dell Financial Services, which is the legal owner of the units, throughout their time in use by RVG. Infocare took the initiative to organise information on used PCs in terms of detailed descriptions of their precise location, delivery/collection dates, technical specifications and the age of the products. This informational structure enabled the appropriate management of physical flows, which were planned and executed together with the other actors involved in the project. In this and other similar projects, the primary task of Infocare is to coordinate parts of physical flows, information flows and orders.

Orders are lists that are classified in terms of address, collection/delivery time, product specifications and identity. Information on address, speed of processor, size of the monitor screen, serial number, delivery date, room numbers, name of the organisational unit, user, and telephone number of the exchange coordinator are all included in these administrative lists. These forms are used by other partners and collaborators of IT Logistic and Infocare with the aim of classifying the information needed to collect the equipment. In this way, many organisations that are using the equipment can effectively organise information about their current stock of IT equipment. Several larger public institutions and private companies have gradually developed information systems that keep data about the contract, leasing period, monthly payments, location of the equipment, and technical information about product attributes. Modern telecommunication systems facilitate the rapid transmission and storage of information between the project participants.

IT Logistic and Infocare are able to create customer-specific adaptations in terms of organising information in lists and forms that support accurate exchanges of information between separate organisational units. As stated above, a suitable informational interface enhances planning and implementation of logistics operations. Classification of information column-wise according to the product’s address, technical features, and collection date, and the identities of disposers, makes it possible to create forms that can support management and processes performed by planners, installers and drivers. Therefore, the aim of an appropriate interface for information exchange is to transfer the knowledge required for materials handling of both new and used products. During the on-site collection, for example, drivers usually compare the address, including the name of the organisation and the room number, with the serial number of the new and used product.

6.4.3 The management of information exchange

When the order from RVG arrives at Infocare it is transmitted to Dell, which can start planning for assembly of the new computers. The order information is also transferred to two other actors in the project, ReuseIT and Igus Data. Igus Data specialises in the reconditioning of IT equipment, and works closely with ReuseIT, a distributor and retailer of recovered computers. After the order arrives, Infocare and IT Logistic may commence with planning routes and capacity utilisation of labour, storage space and vehicles used in the project.

When the project started in 2006, all relevant information about disposers was collected and stored in an information system. Accurate data with regard to collection/delivery date, placement, disposer names, product specifications and serial numbers facilitated more efficient planning of the collection, logistics and distribution of used products for IT Logistic, Igus Data and Infocare. For the transportation planners, it is possible to distinguish a range of zones according to postal codes that depict geographical closeness related to different addresses.

In the end of 2010, Infocare and IT Logistic tried to influence Dell and RVG to create more efficient consolidation within the time constraints of working hours on the level of organisational units. This type of consolidation had been successfully implemented for other public and private organisations. The different organisational units within RVG did not order the collection of all computers jointly at the same time, which decreased efficient geographical and temporal consolidation. Another area of possible improvement was to coordinate spatial and temporal collection from several geographically close organisational units. Apart from taking into account the proximity of end users connected to the same age (and specifications) of the products, this configuration also maximises the number of collected used articles during a given period, since the load carriers are fully employed. This leads to cost-efficient distribution and sales of used computers in large quantities.

Continual improvements in the logistics management have occurred gradually ever since the beginning of the programme for regular replacement of computers. As of 2010, since the information is more reliable, precise and complete, it is also conceivable to create more favourable geographical consolidations within the constraints of working hours. The timely exchange of accurate information ensures full coverage of haulage to isolated business and organisational units, and higher capacity utilisation of trucks. This is made possible by two managers at Infocare and IT Logistic, who use software in order to calculate appropriate capacities and labour hours, and their interactions with time and space constraints. These calculations are based on the classified information, taken from the business system of RVG, when the order for synchronised delivery of new products, and collection of the used ones, is placed. Each month, when RVG sends orders, a manager at Infocare creates an Excel file from the standardised form. Information about the agreement and the price of each product is erased, as these data are not crucial for delivery and collection. The data that supports collection of the used computers is given to IT Logistic, a third party logistics provider, whose involvement in the project is discussed in the next section.

6.5 The provision and coordination of logistics services by IT Logistic

IT Logistic was founded in 2007 in Växjö. The company had a turnover of 13.7 million SEK and 13 employees in 2013. It has 20 years' experience in services related to IT equipment in consumer and business markets. Its inventory is safety classified due to insurance regulations for the sake of minimising the risk of thefts. Another reason for its high security requirements is the fact that equipment, and the information inside of it, might contain data that should not be accessible to others, apart from disposers. IT Logistic is certified according to Quality and Environment Management Systems ISO 9001 and ISO 14001.

The storage facility in Växjö is spread across an area of 1500 square meters, enabling the firm to stock and classify IT equipment during logistics projects for centralised unwrapping and synchronised delivery of new products and collection of the used ones. IT Logistic specialises in storage, configuration, logistics and installation services for new and used IT equipment. It can perform all of these activities, or only those that are required by its project partners.

Joint project management, logistics planning and implementation is done in close collaboration with several other companies. Infocare is one of the firms that work with IT Logistic. In fact, it was Infocare that performed all the activities connected to physical flows of used equipment before IT Logistic took over these operations. Very low fixed costs for IT Logistic, and the limited space at Infocare's storage facility, were two of the reasons why Infocare decided to outsource centralised unwrapping and integrated delivery of new products and collection of used ones. As of 2010, Infocare provides IT Logistic with order handling and sales organisation for, among other things, promotion of the logistics services involving collection of used or obsolete units. Both companies also manage route planning and physical flows cooperatively.

With regard to collection, route planning for transportation of the used units is tightly coordinated with delivery of the new computers. When the order arrives at the beginning of every month, a route plan is created, taking into consideration aspects such as the types of old and new computers, geographical dispersion of disposers, and the use of small or large vehicles. Certain rules regarding priority concerning these dimensions decide the route. Route planning for the collection is done on a working-day basis, and is grounded in planning for the delivery of the new products.

The duration of collection procedures is crucial in this kind of project, which involves installation of many units on site. Time studies have been performed since these services started, and every step is measured in seconds. Planners at IT Logistic and Infocare estimate how geographical dispersion affects the time for delivery and installation of the new goods and collection of used goods. The number of places or disposing organisational units that can be visited during a day, or, in other words, the quantity that can be collected (and delivered) during a single working day, determines the size of the truck for the sake of the maximisation of the loading rate.

Implementation of the collection of used products from RVG is connected to the delivery of new products from Dell, as units share trucks, storage space, and load carriers during the backhaul to the refurbishing facility. When the new equipment from Dell is delivered by a third party logistics provider, Schenker, to the facility of IT Logistic in Rydaholm, it is classed for transportation to the end users by delivery date. Prior to the delivery, the equipment is unwrapped and loaded inside special cabinets called ‘IT boxes’ (see Figure 6.3), which are also used during collection of the used computers from the workplaces.

In its original design the rolling cabinet was open, without any doors or metal sheets covering the shelves from the sides. The cabinet was mainly used for on-site repair and contained tools used for this purpose. In addition to installation of the metal sheets during the technological development of the cabinet, safety belts were built in the box to fasten the equipment in order to reduce transportation damages on the equipment. The rolling cabinets maximise the usage of the space in trucks, because they are adapted to the dimensions of the ‘standard truck’. This in turn reduces the need for transportation as the frequency of transport decreases. Furthermore, as the cabinets are loaded with unwrapped units, the loading rates of trucks are higher compared to ordinary pallets. The usage of the rolling cabinet also allows for rapid delivery and collection to and from the primary end user (disposer) site, since the load carrier is adapted to Swedish construction standards for indoor environments (e.g. doors, elevators). From the perspective of the drivers, the wheels on the load carriers improve ergonomic aspects of delivery, and make installation more time efficient. Moreover, the rolling cabinet reduces the risk of damages on office furniture compared to the pallets that are brought indoors for unloading.

As each new product is installed at the workplaces of RVG, a used unit is placed inside the cabinet for co-loading at a local hub and subsequent distribution to the remanufacturer. Apart from being constantly fully loaded, the rolling cabinets have wheels, so that they do not have to be lifted onto trucks with forklifts. Instead, at the hubs the cabinets are manually rolled inside the vans for local collection, and then into trucks for regional transportation to the reconditioning facility. This is in line with the policy of IT Logistic to maximise the fill rates by combining the usage of smaller trucks for local distribution and larger trucks for longer hauls. In addition, this arrangement ensures safe and secure transport of the used IT equipment in locked cabinets, owing to the fact that goods are not handled in shared or public facilities. This is an important aspect for the disposers, because the information that can be retrieved from the hardware might be regarded as sensitive (for example, information about patients at hospitals).

Collection from different organisations within RVG is performed by the drivers employed by IT Logistic. Delivery personnel have the knowledge on how to securely pack used units in the specialised boxes on their way to Igus Data. Monitors are wrapped with reusable thin protective plastic and put on the top shelves inside the cabinets, while the hard drives and other heavy equipment are placed on the bottom of the load carriers due to stability issues. The set-up is the same when delivering new units.

The drivers of IT Logistic are given a whole day to deliver, which enables them to coordinate the routes quickly in case of traffic jams or delays triggered by some disturbances during the collection of the used equipment. Disposers may, for instance, forget to move all information that is important to them from the hard disks to the server. Another example of these distractions includes a lack of proper communication between different levels of the organisation, which cause certain interruptions in the collection process. Information that is provided on the list might be insufficient or incorrect, thus preventing the products from being localised immediately. Exchange coordinators, who are locally responsible employees for IT issues, and the personnel on site, communicate with drivers on a daily basis to resolve these small issues. Exchange coordinators at RVG, the managers at Infocare and IT Logistic, and the drivers know each other very well, as they communicate and interact on a regular basis. It is routine for the driver to call the division or department around half an hour before the truck arrives in order to remind them about the delivery, and to ensure that they are ready for the collection of the old equipment and installation of the new computers.

From time to time, drivers make small local agreements with organisational units belonging to individual firms and public service providers to leave the equipment for several days in the load carriers at the disposer sites when the local inventories are full. This means that the time for collection becomes more flexible, as the equipment can be picked up the next time the driver is near to the particular disposer site. The used goods that can be collected within the constraints of the working hours per day and geographical space are transported by small trucks to inventories that can store a one-week supply from the local geographical area. Therefore, once a week a larger truck collects the products from this small inventory and transports them to the warehouse of IT Logistic or to Igus Data’s facilities for reconditioning, depending on current orders and capacity utilisation.

The combined delivery of the new IT equipment and collection of the used, without any packaging and in specialised load carriers, makes the logistics and reprocessing operations cost efficient. The used units are unloaded, scanned and stored on behalf of reconditioning companies. Furthermore, in case the reconditioning firms do not have enough space before or after remanufacturing, they can temporarily store the products at the premises of IT Logistic on a national or regional level. Apart from merely carrying through the logistics services, IT Logistic sells IT equipment from its own independent projects to a number of refurbishing companies. However, the largest volume of units handled by IT Logistic is not sold, but simply transported to Igus Data. This firm reconditions the products and distributes them to the new end users. The ‘IT box’ logistics system may be utilised to deliver the refurbished IT equipment from Igus Data to these customers.

6.6 Reconditioning of the used products by Igus Data

Igus Data was started in Växjö in 1988. It is one of few companies that survived since second-hand IT equipment began to be traded in the 1980s. Igus Data reconditions laptops, printers, desktops and anything else regarded as IT equipment today. Its mission is to find a second end user or buyer, and to avoid recycling as long as possible. Even if the equipment is five or more years old, there are donation programmes that cooperate with Igus Data who might be interested in the second-hand products. Recycling is regarded as a failure, as it is the most resource-demanding reprocessing alternative from an economic and environmental viewpoint. Besides taking into consideration environmental and commercial issues, Igus Data has a set of priorities related to the disposers and the products themselves that it tries to follow. The first priority is security, which includes deletion of information as a service paid by the disposers or electronics manufacturers such as Dell. The second priority is to identify the product features as accurately as possible for the sake of selling, and the third priority is to restore and guarantee the functionality of the products.

Igus Data has an output ratio of approximately 75,000 units per year, and there are eight employees in the company. The industrial unit for reconditioning occupies an area of approximately 350 square meters. The plant is under video surveillance according to a requirement from the PC manufacturers for information security reasons. Dell obliges Igus Data not to permit filming or photographing within the reconditioning area. The main difference between the distribution of the new and used products is the greater focus on information security, since this is normally not an issue in the marketing and purchasing of new equipment. Hence, all user-created data has to be erased at the premises of Igus Data in accordance with the instructions of the disposers. For instance, RVG has information about patients stored on hard disks that is absolutely not allowed to leak out. Other disposers have even stricter policies with regard to information security, in order to prevent business secrets from emerging. These organisations prefer then to delete information at their own premises, which is done by personnel from Infocare. This implies in its turn that Igus Data only checks the functionality of the equipment, in addition to controlling damage caused by the materials handling processes.

6.6.1 Product recovery operations at the reconditioning facility

The maximal refurbishing capacity of the Igus Data plant in Växjö is 500–600 units per day. Nevertheless, even though Igus Data tries to keep its machines fully utilised, the factory usually processes 200–400 units daily. When IT Logistic delivers the used products to Igus

Data, each article is registered and scanned into a database, after which the physical flow becomes divided into three main materials flows.

Some goods are passed on to be recycled directly after arrival at the refurbishing facility, which is referred to as the first materials flow. Mice, keyboards, and cables are inexpensive and usually the most visually 'damaged' accessories. In addition, new mice and keyboards are added to the reconditioned computers by large traders or retailers – that is, the collaborators of ReuseIT. Hence, keyboards, various other accessories, and electronic and electrical waste from the premises of Igus Data are placed inside the load carriers to be collected once a week by a recycling firm, SITA. SITA classifies the waste into a number of fractions, and sends these for more thorough classification at the reprocessing facility of a materials recycling specialist, Kuusakoski (see section 6.8 for a fuller description of SITA's operations).

The second materials flow concerns equipment that does not contain any information, such as monitors. Monitors are tested and cleaned by highly experienced workers who, due to their expertise, are aware of the places where the products usually have scratches and other types of physical damage. This enables a quicker inspection procedure compared to an ordinary buyer or end user of the second-hand articles. If found to be damaged, these units are discarded and stored in order to be recycled. In this manner, part of the second materials flow becomes connected to the first flow.

Every component that contains some information must go through a data-erasure process, which is the third materials flow. Two types of software applications are utilised to erase the disposer-created data: Ibas and Blancco. Igus Data uses both software packages, as different companies are used to the different kinds of reports that these programs generate. Although both of the programmes are almost 100 per cent secure in terms of their data-erasure ability, Blancco is the most common application of this type in the reconditioning industry. Nonetheless, irrespective of whether it is Blancco or Ibas that is unable to delete the information, an electromagnet is employed to destroy the information in the hard drive and other data-storage media. Then, in order to further ensure the complete removal of information, these parts and components are physically split into pieces, which are then stored on a pallet that is dedicated to the goods that are to be recycled (first flow). Therefore, at this point in time the first and third materials flows come to be interspersed.

Blancco is then used to test the functionality of the products out of which all disposer-created information has been removed. Blancco controls approximately 100 functions and definitions. This test guarantees that the hardware, such as memory, hard drive, network card and motherboard, are in working order. The outcome is a report, which serves two purposes. For Dell and RVG, acquisition of the document that guarantees deletion of information inside the units is the most central issue. For Igus Data, on the other hand, the report gives a clear picture about the features of the item, which are of great significance for sales of the equipment and the replacement of components in the product. The technical details and all available information about the product attributes from the report are stored in the information system by means of the article numbers. This information is then sent to the sellers responsible for the marketing of refurbished products in order to communicate the quality and quantity of functioning models.

If Blancco identifies a defective unit, a decision regarding whether it is profitable to replace modules has to be made. In other words, a decision must be made as to whether it is worth spending an hour on fixing the machine in relation to its current price. This comes down to a combination of professionalism and knowledge held by the refurbishing workers, and by the sales representatives concerning the sales potential of particular refurbished units. There are no detailed instructions or manuals on how to make decisions with regard to reconditioning or recycling. Nevertheless, the knowledge of technicians at Igus Data determines the reprocessing alternative that is chosen; some equipment is merely cleaned and reused, while other defective products have to be repaired, recycled, or refurbished. From time to time, when a comparatively large batch of computers with similar features is processed, Igus Data keeps a small inventory of the used components that are retrieved from erroneous products within the batch. These components are then placed in other units. Furthermore, when needed, Igus Data buys new or refurbished components from distributors or other refurbishing companies and recyclers so as to assemble a load of similar goods.

6.6.2 Distribution of products from the reconditioning facility

When it comes to distributing the reconditioned equipment, an EU Directive obliges Igus Data to trace every load that leaves its premises, and most of the modules are connected to a track-and-trace system so that shipments may be followed. The inspection protocol generated by the Blancco software application enables traceability of the machines through a special serial number. Besides minimising the risk of theft, the purpose of the information system and its tag is to prevent the broken products ending up in countries that have no secure or environmentally friendly way of handling electronic and electrical waste. Hence, the equipment sold to these countries must be in nearly the same working condition as when it was originally sold. Via the identification number enforced by the EU Directive, it is possible to track down the actor and the part of the network that leaked the electronic and electrical waste to countries without sufficient logistics systems for recycling.

However, when the fully functional articles are shipped to these countries from Igus Data, the usage of wrapping is kept to a minimum as the desktops and monitors are wrapped on pallets without the excessive utilisation of cardboard. The laptops are placed close to each other in compartments inside of specialised wooden boxes, without any disproportionate use of paper, cardboard, or plastic packaging. As is the case with pallets, the wooden boxes are adapted to standard truck measurements. To summarise, since there is very little packaging around separate units or components, the loading rates are maximised and the space in vehicles better utilised in comparison with the case when the new products are distributed.

With regard to the coordination of distribution of reconditioned products and the transfer of used units from the disposers to the premises of Igus Data, most of the used IT equipment is delivered to Igus Data's facility 'just in time' for refurbishing. One of the circumstances that facilitate this configuration is the fact that the sales partner of Igus Data has a period of three months to find customers for the reconditioned articles, before the units to be refurbished are brought into the facilities. There are trucks waiting to load the equipment when it has been reconditioned, and Igus Data tries to match the batch sizes in the refurbishing process with the full truckloads. Refurbished goods that have not been pre-sold are kept in inventory at the same facility where the refurbishing takes place while the sales personnel of ReuseIT look for buyers. ReuseIT and Igus Data are located at the same facility and have a common past history, but have become two separate corporations that work together. Until 2008, when ReuseIT was founded, both distribution and reconditioning were conducted within Igus Data. The next section presents a more thorough description of ReuseIT.

6.7 Sales of the reconditioned equipment by ReuseIT

With a turnover of more than SEK 40 million per year, ReuseIT in Växjö is the largest and fastest growing Swedish company for sales of used IT equipment to public and private customers. ReuseIT is part of Norwegian Green Tech Group, which is the biggest player that manages purchasing, refurbishing, and distribution of used IT equipment in the Nordic region. Moreover, ReuseIT is also involved in the HP Renew programme, whose aim is to redistribute leased, rented and surplus stock products. Together with its business partners, ReuseIT delivers thousands of computers every month, for which the firms, in cooperation, provide a 12-month warranty service and customer-specific installations of refurbished units.

6.7.1 Management of supply and demand

Thanks to close cooperation with the lessors, which are the largest PC manufacturers in the world, most of the equipment sold through ReuseIT has been rented or leased over a period of three years. As is the case with the used units, which are disposed of by RVG, the business relationships between the disposers, PC manufacturers, and reprocessing firms facilitate the sharing of information about the quantity and quality of used products and their delivery date prior to their actual arrival at Igus Data and ReuseIT. However, neither ReuseIT nor Igus Data has a commercial relationship with the disposers, including RVG. Infocare sends information about the delivery time for the used products from RVG through the same form that is used by IT Logistic and Infocare to plan integrated delivery of the new products and collection of the used ones. During the sales process of searching for customers for the refurbished devices, the product attributes, such as addresses, prices, pick-up/delivery dates and times, and names of the actors that handle the products, are changed and registered. The sales staff of ReuseIT keeps itself updated with respect to the changes in prices and corresponding technical specifications. The price lists are updated monthly and transmitted to Igus Data, where the lists serve as support for product classifications with regard to various product recovery options. Thus, if these corrections are done poorly, or if the price lists are not updated often enough, there is a huge risk of losing the whole profit.

A great proportion of the price comes from the license or the right to install the operative system, and ReuseIT trades with licenses separately from the marketing and purchasing of the hardware. The operative system itself is usually installed by ReuseIT's business partners, such as brokers that specialise in the distribution of second-hand IT equipment. These intermediaries split up large batches of similar products according to the individual demands of customers. It is the job of these brokers to individually manage each new or secondary end user, and the economies of scale that are generated during collection, transportation of the used computers to the reconditioning facility, and reconditioning of the equipment. In this way, a relatively large number of a few product models from RVG create economies of scale, as they can be treated similarly in administration and reprocessing. Another enabler of the economies of scale is the fact that many used products have been utilised for the same amount of time. Consequently, the expected quantity of products that have a value for secondary end users can be roughly estimated and forecasted.

As a result of the prior knowledge of the characteristics of the equipment that will be refurbished, ReuseIT can follow the prices on various trading sites for used units, which are either closed or open to the public. Trading sites, and relationships with other brokers of refurbished products, make it possible for ReuseIT to search for customers of a certain second-hand product class and sell the equipment before it actually enters the facility for reconditioning. Hence, for instance, when a second-hand broker wants to buy a certain reconditioned product, ReuseIT can search for this kind of product even among competitors, while the products themselves can be as far back in the network as at the disposer sites. Another example is when a large corporation wants to extend the life of its PC assortment in use by replacing a single malfunctioning product. Therefore, instead of exchanging all computers, ReuseIT can help to find computers that complement the existing PC environment of a customer. In this way, ReuseIT can assemble different offerings for the customers of refurbished units through the information systems, without having the physical artefact at hand.

ReuseIT and Igus Data export around 85 per cent of the reconditioned products. These units are distributed to 10 partners in Eastern Europe, Southern Europe and other parts of the world. In certain cases, these partners have very low financial credibility, which compels Igus Data to demand payment in advance, rather than extend credit. The fact that some of these countries do not have well-developed systems for financial control practically forces this arrangement upon ReuseIT.

Pertaining to the financial arrangement with regard to the procurement of logistics services, international buyers of remanufactured equipment often take care of the ordering and purchasing of transportation. When it comes to arranging, planning, and coordinating the distribution activities, the buyers abroad and their logistics partners try to avoid any loadings and reloading en route, because such inexpensive equipment cannot carry the costs of handling redundant materials. Since the price per unit of the used and refurbished equipment is low, it must be distributed in large quantities. The longer the distance and the cheaper the product, the larger the load carrier; or in other words a more scale-efficient transportation method (such as sea transport) may be used. For example, as the prices of the used equipment are decreasing at between three and five per cent every month, it becomes crucial for buyers located further away than 3,000 kilometres to have a large load of products, such as containers, which often take time to fill up.

Approximately 15 per cent of the used equipment remains in Sweden. The Swedish customers of second-hand products include municipalities, schools, and other organisations. This trade is completed via the Internet, or through existing business contacts. In Sweden, ReuseIT gives credit to established buyers with whom it has long-term business relationships. In collaboration with ReuseIT, Infocare takes care of warranty repair services in Sweden. The different logistics structures of the repair services have been discussed in section 6.4.1.

6.7.2 Transportation of the reconditioned products from ReuseIT

When it comes to the transportation arrangements from ReuseIT, there are several options available. The first solution refers to the desire of a secondary end user to order a large quantity of PCs that are to be installed on-site. In such a case, IT Logistic can be made responsible for the software installation and delivery, as described above. Another alternative is associated with the sale of a single or a small number of computers to a Swedish end user. For this kind of transportation service, ReuseIT employs third party logistics providers – that is, Schenker or Posten – since the value and quantity of the consignments are usually too small for a distribution structure that involves a single truck going directly to the customer. Via a form that is used to structure and frame data about the delivery, the order is transmitted from the purchaser of the product through ReuseIT to a logistics service provider; that is, IT Logistic, Schenker, or Posten. These logistics service providers pick up the reconditioned equipment and distribute it through the hubs, where the shipments are temporally and spatially co-loaded with other consignments coming from many more senders and receivers.

Schenker and Posten require information about the weight, size, and article number with the associated information in order to generate a unique consignment number, which facilitates an efficient way to manage distribution and materials handling activities, and the related resources, such as trucks and automated conveyor belts. In terms of identifying, tracking, tracing, and physically handling the equipment, similar procedures are followed by the third party logistics providers regardless of whether the equipment is about to be reused or recycled. The geographical location of the facilities for recycling or dismantling is highly influential in the determination of routes.

Managers at Posten and Schenker classify orders from many customers according to the delivery date in order to consolidate shipments. Barcodes that are attached to the shipments from IT Logistic are scanned when they come to the inventory facilities. Here, they get a stock number in order for the shipments to be identified when they need to be loaded onto trucks for delivery to consignees. The truck driver usually receives the phone number, as well as the address of the consignee. This makes it easier for transportation firms to find the right place, which is a department or a business unit. Transportation is one activity conducted by the recycling firm, SITA, whose operations and assets are presented in the following section.

6.8 Collection of electronic and electrical waste by SITA

SITA Sweden is a leading recycling and waste-management company. The organisation is part of a larger global company called Suez Environment. SITA has 1100 employees and local offices in most of the larger municipalities. SITA offers customised solutions in waste management, recycling, and transportation all over Sweden. It takes care of all kinds of waste, except for radioactive substances and explosive materials (these two classes of products are the responsibility of the police department).

Electronic waste is a minor business segment for the regional office of SITA in Älmhult, as the company is more specialised in the handling of hazardous waste, including solvents, different kinds of machine oils, batteries, acids, and many other product groups. It considers this handling to be its niche, even though it offers a complete waste-management solution. The neighbour of SITA in Älmhult is SAKAB. This firm has a processing facility for hazardous waste in Kumla. SAKAB co-loads and stores hazardous waste from SITA and other actors in Älmhult, and sends full truckloads to the processing facility.

When a disposer initiates a business relationship with SITA, one of the sales representatives from SITA travels to the site in order to investigate the type and quantities of waste that the particular disposing organisation has. This information enables SITA to deliver several smaller waste load carriers, which represent various raw materials groups, inside of a larger container. The load carriers are tailored product sections, which are adapted in accordance with the waste classes that the disposers produce. This is how SITA creates customer-(disposer-) specific adaptations. For example, mechanical workshops and farmers have the most universal waste solutions and sections, as they have all kinds of waste. One group of scrap is labelled electronic and electrical waste, which is a broad group of products that include light bulbs, battery chargers, cables, home electronics, PCs, office printers, monitors, keyboards, and mobile phones.

The waste load carriers are checked once a year to help the disposers to acquire containers of appropriate sizes, whose content would match different types of waste, and thus the waste sections. The regional office of SITA in Älmhult has an employee whose task is to make visits to the disposer sites in order to inspect how the load carriers are handled. This employee performs continuous checks with regard to aspects such as new production processes, products, parts, and materials, as changes in these dimensions might affect the waste composition. If SITA is not properly informed about these modifications, it becomes difficult to achieve maximal loading rates as varying sizes and kinds of vehicles are needed for different types and quantities of waste. Thus, fluid waste, for instance, has to be picked up by the tank trucks, while electronic and electrical waste and solid scrap can be transported by 'ordinary' trucks. In addition, SITA aims to have all waste sections inside the containers or cabinets completely filled when the trucks are about to collect them from the disposer site. A more detailed description of how collection of waste is carried out and how this procedure is coordinated is provided in the following section.

6.8.1 The logistics management of waste collection from the disposers

Collection of waste is usually ordered by the disposers (such as Igus Data) when the load carriers at the disposer sites are full. SITA arranges transportation and plans routes for each day in order to maximise the fill rates and minimise transportation costs. There is no standard or fixed lead time between the order placement and collection of waste due to the huge variations in dates, volumes, locations, and types of waste. The Transportation Manager divides the area of 150 kilometres from Älmhult into a number of smaller geographical zones and corresponding periods of time to which collection trucks are assigned. Thus, if a certain disposer orders a collection during a week when SITA gathers waste from geographical areas other than the area in which this disposer is located, it has to wait for waste collection.

Hazardous solid waste and electronic waste are collected simultaneously by the same vehicles but in separate sections, since they can be shipped in 'ordinary' trucks. Another reason for their joint transport is the fact that there is not enough of each of these product groups within the radius of 150 kilometres from Älmhult in order to maximise the fill rates. Similarly to the hazardous waste, the electronic and electrical waste in general, and from Igus Data in particular, is collected in a cage and fixed to a pallet. SITA in Älmhult uses its own transportation for most of the orders it receives. For that purpose, it has five tank trucks and two ordinary trucks. Extra transportation capacity is provided by Schenker.

After the day of collection the drivers deliver goods to SITA's facility, where it is unloaded and classified into different fractions. With the aim of generating economies of scale in transportation, SITA waits until 45 pallets are filled in order to deliver this load to two reprocessing facilities for electronic waste under the control of Kuusakoski. In an attempt to minimise the transportation costs, SITA and Kuusakoski have agreed to recycle the electronic waste in two of Kuusakoski's industrial units that are geographically closest to Älmhult. These two facilities are situated in Korsberga and Karlshamn.

6.8.2 Classification of electronic goods for recycling

Initially, SITA in Älmhult did not classify electronic waste as it sent pallets with mixed unclassified electronic waste to Kuusakoski in the same state as it came from disposers. In that way, SITA was a transportation company in its relationship with Kuusakoski, which charged SITA for the classification of goods. SITA noted that it was losing money on each unclassified shipment of electronic waste in comparison to the financial amount it charged for the service of waste collection from the disposers. Personnel from Kuusakoski showed SITA how to classify the electronic waste so as to improve the overall profitability of the logistics processes associated with the handling of waste for both partners in the commercial relationship. In practice, it is a specialist from Kuusakoski that gives advice to SITA on dismantling and classification each time a new product or model becomes part of the waste flow. In 2011, SITA disassembled and classified the parts and accessories of a computer into monitors, cables, printed circuit boards, keyboards and mice. Figure 6.4 shows a range of classification groups.

Figure 6.4 Different classification groups of electronic waste.

There is a price attached to each of the fractions, and SITA obtains information about the price changes for each class and fraction on a day-to-day basis through Kuusakoski, which sends these details in the form of a price list. When the employees at Kuusakoski receive goods, they control and measure the weight of each product group in order to refund SITA for the materials sent from Älmhult and surrounding areas.

Gold and copper are two of the most valuable and demanded materials that Kuusakoski and SITA handle. In 2011, the price of gold in the global market increased by 33 per cent; during that same year, SITA received the highest monetary compensation for the printed circuit boards due to their gold content. An empirical description of the network that transforms the copper inside of the printed circuit boards was provided in section 4.10.

Owing to the fact that even installation cables contain copper, Kuusakoski instructs SITA on how to cut the cables in a form that is adapted to its machines. Thus, the machines at Kuusakoski's facilities in Korsberga and Karlshamn remove the plastics and aluminium around the copper core of the cables from SITA in Älmhult. Besides copper and gold, all materials are processed further on in order to achieve as high purity as possible by testing their properties. For instance, infrared light is utilised to distinguish different kinds of plastics.

6.9 Summary

This chapter has shown that extensive and accurate information-sharing between the disposer, RVG, the project coordinator, Infocare, the logistics service providers, such as IT Logistic, Schenker, and Posten, the refurbishing company, Igus Data, and the broker of second-hand products, ReuseIT, accommodates coordination of the physical flows for the reconditioned IT equipment. The structured administration of information about the products by the various organisational units of RVG facilitates regular purchasing of the new, and disposal of the used, products on a three-year basis. Information about the products that are to be disposed of becomes available to the potential secondary end user before they are received by Igus Data. This implies that the products can be sold while they are still at the disposer site and in use by the organisations that will eventually discard them.

With regard to recycling, the close collaboration between the recycling company, Kuusakoski, and the collector of electronic waste from Igus Data and ReuseIT, SITA, enables development of the techniques for the goods classification and product disassembly. These developments create efficiency improvements in the materials handling. Apart from these adaptations, ReuseIT and SITA continuously adjust the containers and load carriers for a range of qualities and quantities of materials that are distributed from Igus Data to SITA. SITA's facility in Älmhult serves as a collection point for various kinds of waste besides electronic waste.

7 ANALYSIS RVG

This chapter provides an analysis of the handling of used PCs from RVG. Apart from the empirical findings in Chapter 6, the analysis is partially based on the data in sections 4.9–4.10, as the activities, companies, and resources described in these sections are relevant for the case analysis in this thesis. Supported by the tools presented in the thesis framework, empirical findings are analysed in three layers of the Industrial Network Approach; that is, activities, resources, and actors. First, the activity pattern will be analysed with respect to the concepts of transvection, activity interdependencies, similarity and complementarity, crossing and differentiation points, and the principles of postponement and speculation. Then, an analysis of the resource constellation based in the 4R model will be conducted. Finally, the third part of the case analysis will be focused on actor interaction, information sharing, classification systems, and the nature of business relationships.

7.1 Analysis of organising product recovery in the activity pattern

This analysis of activities takes its starting point in three transvections that highlight different ways of organising product recovery with regard to temporal organisation of activities, and with respect to multiple reprocessing options performed by a number of actors (sees Table 7.1). Transvections 7.1 and 7.2 are discussed in order to scrutinise the application of the principles of postponement and speculation with regard to refurbished objects. Transvection 7.3 is organised according to the principle of speculation. Furthermore, this transvection contributes to the understanding of sorting in the form dimension as an activity that directs the object into alternative product recovery options, since the object is distributed into a recycling facility and, further down the transvections, to the manufacturer of the copper wire rod, Elektrokoppar.

	Product recovery/reprocessing option	**Principle of postponement/speculation**	**End destination**	**Actors involved in addition to the disposers**
Transvection 7.1	Refurbishing/ remanufacturing	Postponement	End user	RVG, IT Logistic, Igus Data, Logistics Service Provider, broker, end user
Transvection 7.2	Refurbishing/ remanufacturing	Speculation	End user	RVG, IT Logistic, Igus Data, Schenker, end user
Transvection 7.3	Recycling	Speculation	Manufacturer of copper wire rod	RVG, IT Logistic, Igus Data, SITA, Kuusakoski, Schenker, Boliden, Green Cargo, Elektrokoppar

Table 7.1 Analysed transvections in terms of their reprocessing option, organising principles, end destinations, and involved actors.

In the next section, the focus of analysis is on this joint movement of objects from RVG. Therefore, this common path of Transvections 7.1–7.3 is analytically described below.

7.1.1 Common path of Transvections 7.1, 7.2, and 7.3

All three analysed transvections share a common physical flow, as depicted in Figure 7.1. This route goes from the disposer, RVG, via IT Logistic to Igus Data's facility for refurbishing and testing of objects. Transvections 7.1–7.3 are activated when individual disposers at RVG place an order for collection of the object. In all of the transvections described in this section on organising product recovery in the activity pattern, the object that is collected from RVG is a PC; that is, a collection of objects that include mice, keyboards, monitors, and hard drives. These features define the object in its form dimension, and have to be translated into data that is shared between disposers the – Infocare,[40] IT Logistic, and Igus Data – so that these actors can coordinate physical flows from RVG to Igus Data's reprocessing facility.

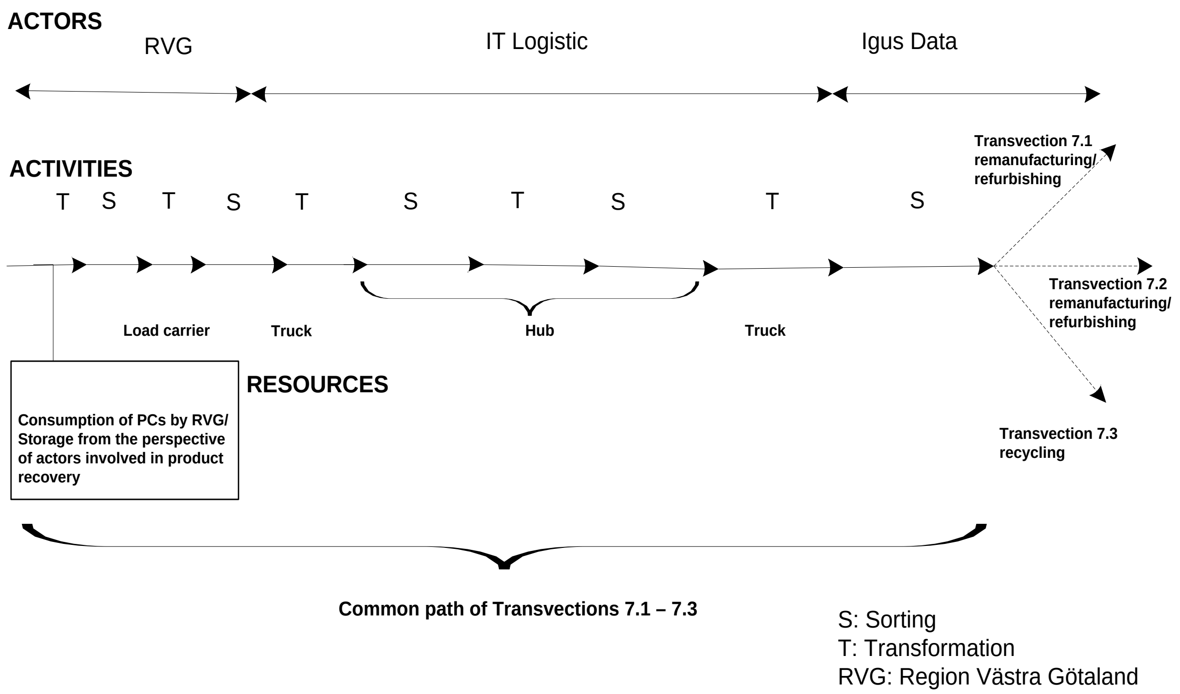


Figure 7.1 Common path of Transvections 7.1, 7.2, and 7.3.

In order to facilitate efficient information exchange between actors, the time, place, quantity, price, and identity characteristics of objects have to be defined, in addition to the proper description of the object's form features. Hence, order information is classified into time, place, form, quantity, price, and identity dimensions, which are tied to the article number of each object. That is to say, each article number contains information about the collection/delivery date, placement in the workplace (floor number, room number, etc.), form features such as the size of the screen, and other characteristics related to the form utility.

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[40] Infocare does not handle the disposed PCs physically, and is therefore not depicted in the transvections. Rather, the company participates in coordination of activities and information exchange.

With respect to the identity dimension of the object, information is provided about the disposer/current user, including their name and the name of the organisational unit.

The Service Manager at Infocare, and the Managing Director at IT Logistic, use this information in combination with different rules for time, place and form transformations to plan synchronised delivery of new PCs and collection of used ones. Software is programmed according to rules that optimise routes for collection of used PCs. These route plans for collection of objects, which include data about form, time, place, and identity object dimensions, are distributed to IT Logistic's drivers. During the collection of used PCs, these drivers interact with the personnel at several instances within RVG organisation on a daily basis. Interaction with employees at different organisational levels inside of RVG, such as exchange coordinators, IT-responsible personnel, and other employees, makes sorting and transformation at RVG's premises less time-consuming.

From the disposer site, the used PC is assigned to the specialised load carrier on wheels. After approximately eight hours of collection, the objects are assigned and transported to a hub in Gothenburg, which belongs to IT Logistic. Later on, and in order to exploit similarities, objects are transferred in a larger truck (relative to the one that collected objects on a local level in Gothenburg). Units in the larger truck are assigned to Igus Data's facility in Växjö, where, after testing and refurbishing, the objects are assigned to different places, delivery dates and buyer identities.

Immediately after their arrival to Igus Data's facility, the objects are discharged into the unloading area of the testing facility. A sorting rule concerning objects that do not contain information assigns mice, keyboard and cables to a pallet for recycling, as they have a very low monetary value. Consequently, mice, cable and keyboards are assigned to a pallet that has been selected by a collector and dismantler, SITA.

Owing to the fact that disposers must release used objects every third year, it is possible to plan the sequential path of used objects. Generated uniformity in form, time and place enables objects to be sequentially collected from the same area during the same period of time in all transvections.

Several types of sequential activity interdependencies and complementarities are present with regard to uniformities and distinctions among objects, and between actors. Transvections 7.1–7.3 are complementary until they reach Igus Data, as all assignments and selections of objects have been predetermined. This includes collection of used PCs to the local hub, storage at this local hub, and transportation between the local hub and Igus Data's refurbishing facility in Växjö. At this facility, objects can be differentiated into various dimensions associated with current demand.

Activity similarities are means by which to create economies of scale in operations, since firms cannot ship or manufacture objects economically if only activity complementarities are taken into consideration. The starting point of the analysis is at the disposer, RVG. Since the number of PCs leased to RVG is so large, several drivers might be used to collect the old computers during a single day. Therefore, parallel dependence is an attempt to economise on time, and space as it affects time during collection of the used equipment. In this way, activity similarities can be utilised across object collection processes from several organisations besides those involved in collection for RVG, as these activities use similar resources, such as load carriers, where objects are co-loaded. These load carriers – or rather the transformations that they accomplish – are thus crossing points at which economies of scale, mainly with regard to time and place, are used, although the identity of an end user might not be known beforehand.

Specialised rolling load carriers and trucks are other examples of crossing points. A truck is a crossing point as it is filled up with two load carriers and transported to a local hub. The truck, which that transports two load carriers during one day of local collection generates parallel dependence for objects. Therefore, there is a similarity in activities and parallel dependence in transvections that are bound to the same local hub during the same day. This is because IT Logistic use similar knowledge to perform these sorting and transformation activities. The local hub of IT Logistic is a crossing point as goods are stored here simultaneously, implying parallel dependence and activity similarities since inventory holding requires same kind of physical resources for sorting and transformations.

At the hub, objects need to be assigned to a specific spot, according to rules for identity, time and place. This is because the local hub in Gothenburg may hold objects that are assigned to other actors' facilities in addition to those assigned to Igus Data's inspection facility. According to sorting and transformation rules for time and quantity, once a week a larger truck picks up the objects that have accumulated during the week at the local hub. Objects are jointly assigned to this crossing point by IT Logistic for economies of scale in transportation over a larger distance; for instance, between a disposer in Gothenburg and Igus Data's facility in Växjö. The joint assignment to the crossing point, a hub, is organised in this manner in anticipation of economies of scale or parallel dependence in another crossing point, the truck headed for Igus Data, to be sufficient to justify transportation over a larger distance.

RVG's combined purchasing and disposal of a few standard PC models in large quantities on a three-year basis does not merely reduce administrative and distribution costs per unit of product by means of activity similarities. In addition, the procedure generates uniformities in form and time dimensions, which are exploited in the crossing points of the purchasing department since delivery of 700–800 new, and collection of 700–800 used, objects per month are ordered simultaneously. For instance, collection of used objects from RVG is pre-planned and coordinated with regard to spatial proximity between objects that are located in different organisational units or departments, such as hospitals or health centres. In this way, it is possible to achieve economies of scale in transformations and sortings without any excessive speculative inventory holding, as objects travel from their location at one of RVG's disposing organisational units to Igus Data's inspection and refurbishing facility.

Inventory holding at the crossing points is only necessary for the generation of appropriate parallel dependencies attributable to time and place discrepancies. These discrepancies are reflected in the assignment of objects to crossing points, such as vehicles for short hauls during a single day's collection of objects from RVG to a local hub, and transportation of a greater number of objects collected during the week over longer hauls. In other words, shipments over long hauls by aggregated crossing points – that is, larger trucks – are delayed in order to distribute the costs of transformations in time and place across several objects.

At Igus Data's facility in Växjö, activity similarities are created in several ways, although monitors and hard drives are separated into activity structures that require distinctive types of knowledge and resources for refurbishing. In this manner, objects can make use of specialised resources in order to achieve economies of scale, and efficient utilisation of resources for sorting and transformation. Moreover, several units of the same type/form, such as hard drives, can be tested by the same equipment simultaneously, implying that this crossing point can process the objects according to sorting and transformation rules and feature values of the hardware. These crossing points are dependent on form classifications of the object, as they rely upon input and output values that are closely related to object form specifications. In contrast, dissimilar objects in the form dimension can use the same transformation resources (crossing points), such as forklift trucks, pallets, and other load carriers for materials handling, packaging and loading into trucks.

7.1.2 Transvection 7.1 – remanufacturing and postponement

As stated above, Transvections 7.1, 7.2, and 7.3 share a common path between RVG and Igus Data. At Igus Data's facility, all of these transvections get distinctive directions. Thus, actors and corresponding facilities involved in Transvection 7.1 include disposers (RVG), IT Logistic, Igus Data, a logistics service provider, an international broker, and an end user.

After the first sorting at Igus Data, which is concerned with mice, keyboards, and cables that go to be recycled via SITA, additional tests are performed in order to make a distinction between objects in several dimensions. According to a sorting rule regarding transformations of objects based on the existence of information inside of them, monitors and hard drives are assigned to different transformation resources. In other words, hard drives become assigned to specialised equipment for data erasure, while monitors get assigned to machines that test their functionality. This separation of physical flows is depicted in Figure 7.2.

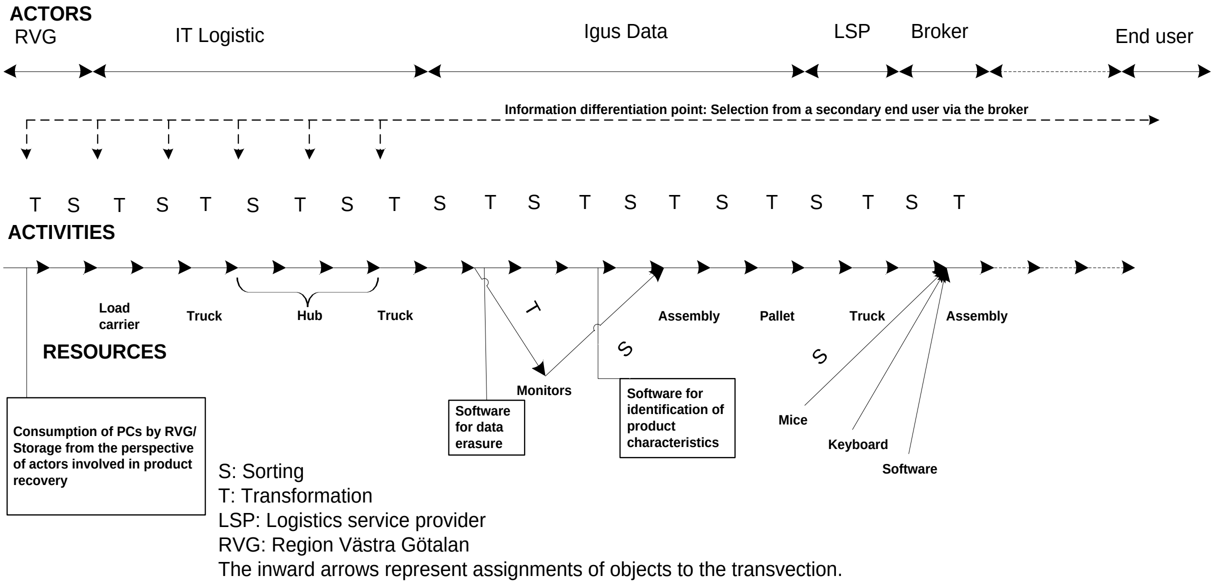

Figure 7.2 Illustration of Transvection 7.1.

In this way, hard drives are assigned to software that performs a form transformation by deleting all disposer-created information. An additional rule, concerning the existence of information inside of the object after this step, guides the object to the next transformation. If there is any data left inside of the object, it is transformed by an electromagnet for complete data erasure and assigned to a pallet for electronic waste. If there is no information left in the device after data erasure, specialised software sorts objects by identifying and comparing object features. These attributes are framed by the limits provided by the sales staff of an intermediary, ReuseIT.[41] By identifying object properties, such as processor speed and amount of memory, it is also possible to select functional components. These components can then be assigned to other functional objects in either Transvection 7.1 or 7.2.

If the international broker has preselected a sufficient volume to fill a truck, the tested objects from the refurbishing facility are assigned to a truck in Transvection 7.1 (see Figure 7.2). In this case, the receiver of a refurbished PC has used sales managers, catalogues on the Internet, or other types of communication to make a selection from ReuseIT several weeks or months before the refurbishing process takes place. Personnel at Igus Data assign all sorted (tested) objects to a pallet, which is wrapped and then loaded on a truck belonging to the Logistics Service Provider. At this point in time, the object is assigned by the Logistics Service Provider to transformation resources, such as containers or truckloads suitable for longer hauls, in accordance with the geographical destination of the object. In this manner, unnecessary sorting of individual objects along the way from Igus Data to the international broker is avoided. The broker differentiates objects with regard to customers as it assigns refurbished PCs with new software, mice and keyboards. These objects are consequently transformed to secondary end users.

[41] ReuseIT does not handle the object physically, and is therefore not depicted in Figure 7.2.

One of the facilitators of the activity complementarity from RVG to Igus Data, and close complementarity from Igus Data to the end user, is inter-organisational sharing of information about the object in use. Such information is sent to various parties for purchasing, capacity and reprocessing planning. For example, in Transvection 7.1 each object can be bought while still in use at the disposer, during the collection by IT Logistic or inspection by Igus Data. Buyers of objects may assign vehicles through transportation companies to collect refurbished PCs when they emerge from Igus Data's facility in Växjö. Igus Data, logistics service providers and buyers of refurbished objects can match their plans qualitatively and quantitatively beforehand, thanks to their knowledge about objects.

The form dimension, in terms of certain characteristics of objects, is largely locked to the object features that were delivered to RVG as new, making it difficult to postpone differentiation in form dimensions of the refurbished units. Nonetheless, postponement in form as in addition of mouse, keyboard, upgrading of certain components, and installation of software is performed by brokers and other types of intermediaries until the final form dimension is determined at the materials differentiation points. This is also a type of postponement, since brokers can purchase PCs in an undifferentiated form concerning software installation, mouse and keyboard. The rest is adapted to specific customer requirements closer to the time of purchase by the end user of a refurbished PC.

With regard to the distribution of refurbished equipment from Igus Data, time, place, and form uniformities created by RVG can generate parallel dependencies in selling activities by ReuseIT, and collection and transportation of used objects by IT Logistic. This implies that ReuseIT can interact with potential intermediaries and end users of refurbished objects in the network, although used PCs have not yet arrived at Igus Data's refurbishing facility. ReuseIT can be regarded as an aggregated crossing point, since it can process an order for a number of objects simultaneously, and in this manner create activity similarities and parallel dependence of information-handling about objects.

Distribution over long distances to international consignees requires a higher degree of parallel dependence in crossing points with respect to truck deliveries of refurbished objects from Igus Data. Here, similarity among activities is a tool to bridge time and place discrepancies for long-haul transportation. The costs of additional sorting increase distribution costs when small shipments are sent over larger distances. Nevertheless, if a small shipment with regard to weight and volume is sent on a longer path, objects go through a hub (a crossing point) where they are jointly assigned to other objects that share the same destination. By applying these sorting and transformation rules with regard to the size of shipments, logistics service providers can use parallel dependencies among place and time transformations with the aim of overcoming space and time discrepancies between many consignors and consignees.

7.1.3 Transvection 7.2 – remanufacturing and speculation

Transvection 7.2 alters the direction at Igus Data's reprocessing facility towards an end user via Schenker. An important distinction between Transvections 7.1 and 7.2 is the point in time at which the order is placed by a buyer of a refurbished PC. In Transvection 7.1, a refurbished PC has been preselected by the buyer, whereas in Transvection 7.2 the object ends up in inventory at Igus Data, waiting for a buyer's selection.

At Igus Data's premises, since monitors do not contain any information they are assigned to diagnostic apparatuses and knowledge of sorting rules related to a range of limits with respect to visual features, damage, size,[42] brightness and other technical conditions. After this sorting in the form dimension, working monitors are assigned to transformation in form by cleaning and packaging. When this is finished, the object is placed in an inventory for a transformation in time.[43]

As illustrated in Figure 7.3, when buyers (such as an end user) decide to buy PCs from Igus Data's inventory in Transvection 7.2, the products are assigned an identity of a certain purchaser. If the object is purchased in the Nordic countries, Igus Data assigns new software, mice and keyboards to the object for form transformation. These objects then go through Schenker's local hub, where they are jointly assigned with other objects coming from the same local area. At this point in time, objects are assigned to the same geographical destination as they are transported to another local hub. From this local hub the object is assigned to an end user and a successive transformation – that is, delivery to the final destination – is performed by one of Schenker's trucks.

[42] For example, during the course of the study, 'thick' CRT monitors were gradually being phased out, as even those that were fully functional would not be purchased.

[43] Monitors that are neither demanded nor functional are assigned to a pallet for electronic waste collected by SITA.

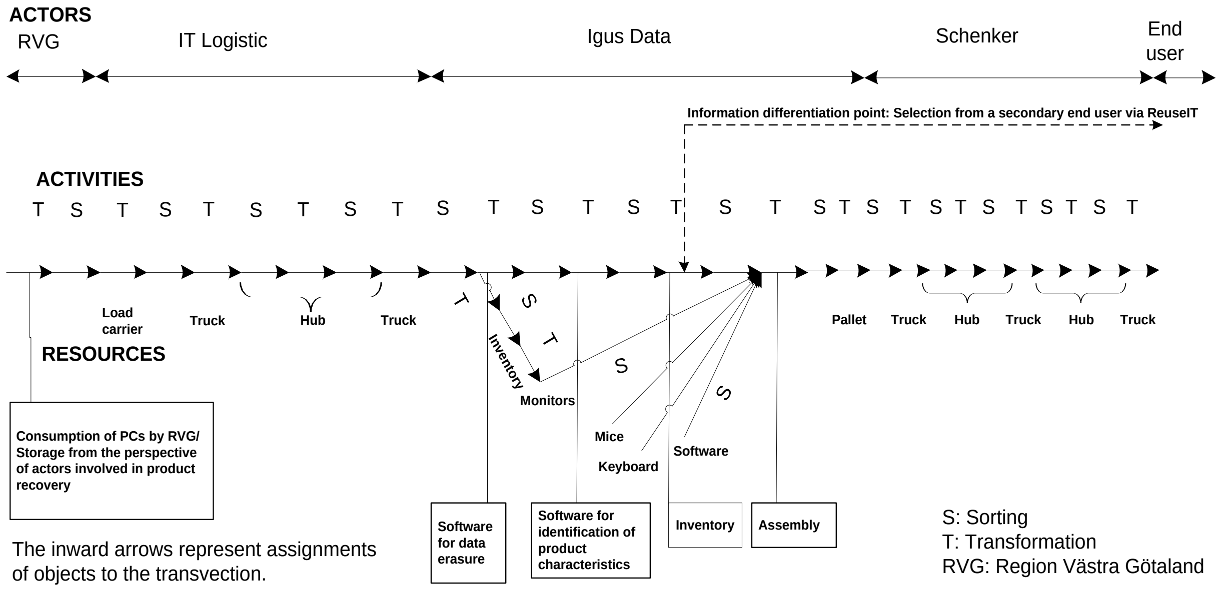

Figure 7.3 Illustration of Transvection 7.2.

Activities in Transvection 7.2 for delivery of new objects, and activities that lead to the delivery of refurbished PCs to secondary end users, are closely complementary with regard to the user from Igus Data. Close complementarity in the network further along the activity structures from Igus Data's premises depends on whether the product is assigned by ReuseIT or Igus Data to an end user. The end user must have also selected the object at the information differentiation points from ReuseIT (for instance, via retailers' or other actors' information systems), in terms of specific features with regard to time, form, place and identity in order to establish close complementarity among activities.

When it comes to shipping, in the Nordic region, ReuseIT can assign used objects to Schenker's trucks and facilities. These logistics firms can deliver the objects to alternative locations by creating similarities in their facilities. These similarities are generated through standardised pallets and trucks, which are headed for the same geographical area at the same time. Schenker is able to handle smaller consignments thanks to its hubs in which packages and pallets are sorted in place, identity, and time dimension towards facilities of various consignees. As mentioned above, the function of the hubs, trucks, and other materials handling equipment is to create crossing points in order to take advantage of economies of scale of objects that could differ completely with regard to the details of the form dimension, except for the size and weight. Crossing points are thus important in generating uniformity among objects and economies of scale, as well as bridging the time and place discrepancies in an efficient way.

7.1.4 Transvection 7.3 – recycling and speculation

Transvection 7.3 originates at the disposer and has a similar activity structure to Transvections 7.1 and 7.2, until the object reaches Igus Data. This transvection includes all of the objects that were regarded as waste in Transvections 7.1 and 7.2. As all objects that end up at a recycler, Kuusakoski, follow a similar path, this path is described in this section about Transvection 7.3. A more detailed analysis of the route that objects take after recycling at Kuusakoski, via Boliden Rönnskär, to the manufacturer of the copper wire rod, was presented in section 5.1.2.

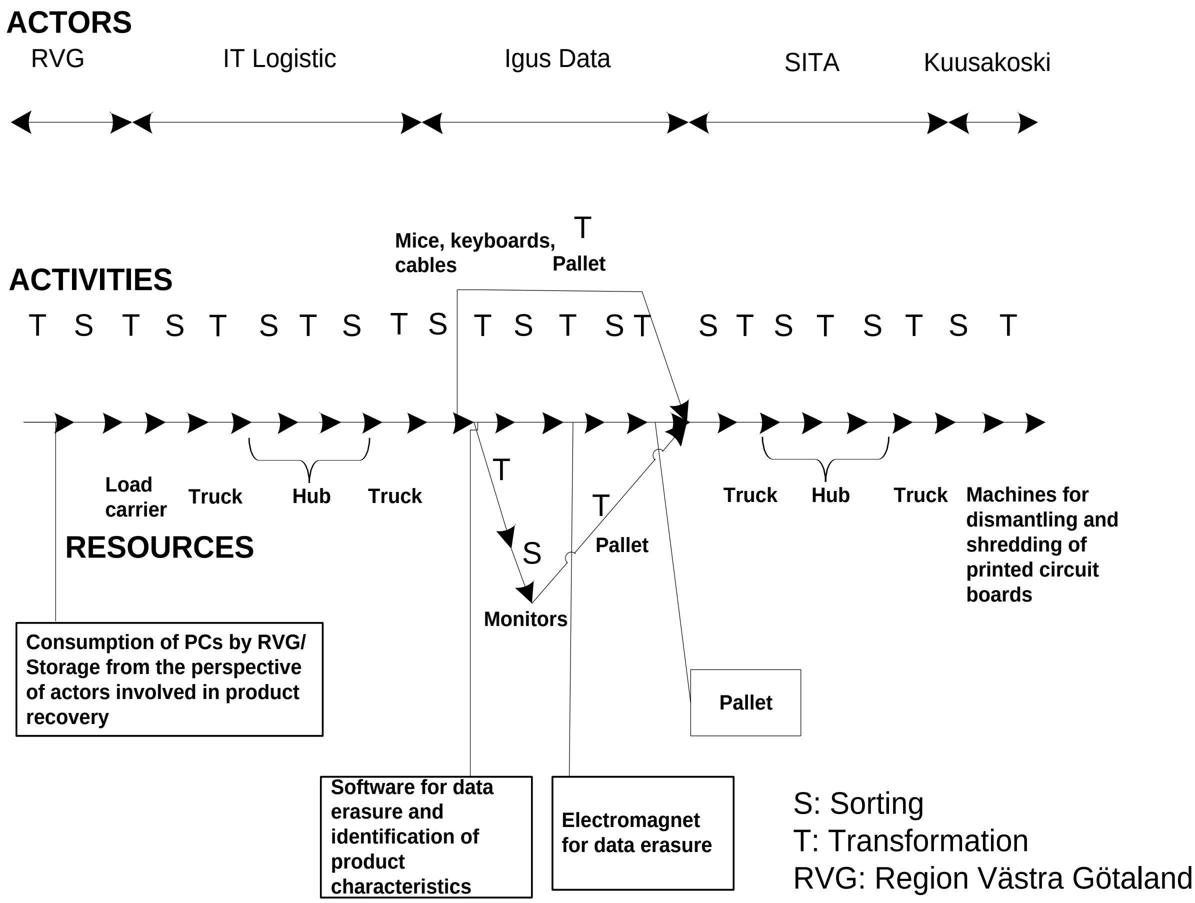

Figure 7.4 Illustration of Transvection 7.3.

Objects in this transvection, which is presented in Figure 7.4, are outcomes of several rounds of sorting according to form, as executed at Igus Data. First, if objects belong to the category of mice and keyboards, they are immediately assigned to a pallet headed for SITA. Second, if the information in objects such as hard drives cannot be deleted, the objects are transformed by an electromagnet that destroys all data. Third, if objects do not have the features required, including non-functional features, they also become assigned to this mixed pallet, which is collected by SITA. This is why this pallet for recycling may contain diverse types of hard drives, mice, keyboards, monitors, cables and other electronic products.

These objects are assigned by Igus Data to SITA, which, in accordance with the sorting and transformation rules of the business agreement, receives predetermined groups of electronic waste from Igus Data. In addition to collecting waste from Igus Data, SITA temporally and spatially consolidates the collection of other types of waste coming from other disposers. For the sake of maximising truck fill rates, various kinds of industrial waste are collected from geographically close disposers during a single day. When the objects arrive at SITA's sorting facility in Växjö, employees select electronic waste from the truck and assign the objects to different pallets in accordance with sorting rules for form (that is, depending on the raw-material characteristics of the objects).

In line with these inter-organisational sorting and transformation rules between Kuusakoski and SITA, the latter company assigns monitors, hard drives, mice, keyboards, and printed circuit boards into palletized boxes, where they are stored. At a later point in time, these load carriers are assigned to a full truck load, which transports them to Kuusakoski. In this way, transformation in time and place by SITA's own vehicles is delayed until assignment to a full truck is executed.

At Kuusakoski's facility, objects are sorted into material fractions according to rules for sorting into metals and other raw materials. Printed circuit boards are assigned to a shredding machine, where their length and width are cut down to 40 millimetres each, and then assigned to a dedicated inventory location until a full truck load (a 20-foot container) transports the shredded printed circuit boards to Boliden Rönnskär; this is carried out by Schenker. This part of the transvection was analysed in section 5.1.2.

From the viewpoint of a PC as a collection of objects, transformations related to some components of used PCs, such as mice, printed circuit boards, cables and keyboards, display complementarity because they are always assigned to SITA, or material defragmentation at Kuusakoski. That is to say, transvections for mice, printed circuit boards, and keyboards are complementary because their paths in Transvection 7.3 are predetermined from the start. Other objects, such as defective or undesired printed circuit boards, monitors and hard drives, are directed towards Kuusakoski after sorting at SITA's facility, implying postponement of differentiation in form. Transvections for used monitors and hard drives are complementary until they arrive at Igus Data, where they may or may not be preselected by a new end user, which in turn affects the presence of complementarity or close complementarity.

Complementarity of sorts and transformations, with regard to their physical properties towards SITA and Kuusakoski, for defective or outdated units of printed circuit boards, hard drives and monitors, is confirmed after sorting at Igus Data. This is because the status of objects is not certain prior to object inspection at Igus Data. Objects are sorted and transformed into material fractions, according to sorting and transformation rules, and reference output values into metals and other raw materials. From SITA, via Kuusakoski, Schenker, Boliden Rönnskär, and Elektrokoppar, the activities related to printed circuit boards that are turned into copper are all complementary and in accordance with the principle of speculation until they arrive at Elektrokoppar. Here, material and information differentiation points coincide as the end user places an order for the copper wire rod from Elektrokoppar. Therefore, the differentiation of identity, time, and place that is coupled with the close complementarity is postponed until the material reaches Elektrokoppar.

Uncertainty of supply from the perspective of Boliden Rönnskär in terms of quantity, time, and place is handled by close relationships with suppliers, who can provide information on the quantity supplied one year in advance. The uncertainty in price related to the form dimension of the supplied circuit boards it is regulated through the price signals of the raw materials exchange and the sampling procedure at Boliden Rönnskär, which determines the weight of gold in each supplier-specific shipment.

In Igus Data’s facility, a delay occurs in order to achieve parallel dependence in the crossing point in form of each box. This serves to create similarities in transportation to SITA’s sorting facility among goods that display greater differences in form compared to in time or place. Objects thus have more uniformity in time, place and identity dimensions than in form, as they are assigned to SITA’s facility. The pallets that contain highly diverse objects from many disposers are handled similarly by the collection personnel. When SITA plans collections from disposers in the same geographical area, its main concern is to create uniformities of heterogeneities in identity, place and time through the crossing points of load carriers and trucks. This is done in order to generate activity similarities and maximise the fill rates of their trucks during a single day of collection.

As the objects arrive at SITA’s facility, employees select electronic waste from the truck and assign parts of these objects to pallets, which are sent to Kuusakoski for material categorisation in accordance with the nature of the product; that is, whether it is metal, plastic, glass, etc. SITA assigns monitors, hard drives, mice, keyboards, and printed circuit boards into specific boxes, where they are stored so that parallel dependencies in these crossing points are created among incoming objects. Therefore, transformations in place are delayed until a full truck – an aggregated crossing point with regard to full pallets – can ship these objects to Kuusakoski. Here, the objects are classified into fractions according to sorting and transformation rules in form related to metals and other raw materials. Upon shredding, printed circuit boards are assigned to a dedicated inventory location, until a sufficient number of them can be sent by a Schenker truck to Boliden Rönnskär. Crossing points can be seen as multiples of each other, since the number of pallets at Kuusakoski has to be adapted to a full truck in order to economically distribute the cost of each pallet position in the truck over time and space.

To summarise, differentiation of transformations in various object classes is postponed depending on a chain of sorting and transformation rules belonging to a combination of ad hoc local and general classification systems. These rules determine the sequential dependence of sorting and transformation occurrences throughout transvections based on reference values of input and output features of objects. Besides coordinating activities in a sequential sense, processes need to be organised in order to take advantage of economies of scale. Crossing points are efficient means by which to handle discrepancies of time, place, form, and identity by generating economies of scale, and in order to link 'the technology of use' to 'technology of production'. By managing activity interdependencies properly at the crossing and differentiation points, it is possible to create economies of scale and end user adapted activity patterns (that is, diversity). The resources that are required for these activities are analysed in the following section.

7.2 Analysis of organising product recovery in the resource constellation

This analysis of product recovery in the resource constellation takes its starting point in the 4R model. In order to avoid repeating analysis of the same empirical findings, readers are referred to section 5.2 for the analysis of the resource constellation connected to Transvection 7.3, from Boliden Rönnskär to the manufacturer of the copper wire rod. The focal resource in this analysis is the object within Transvections 7.1–7.3, a used PC, which is shown in the centre of Figure 7.5. This figure serves as a guide for this analysis, which can be used to follow the discussion.

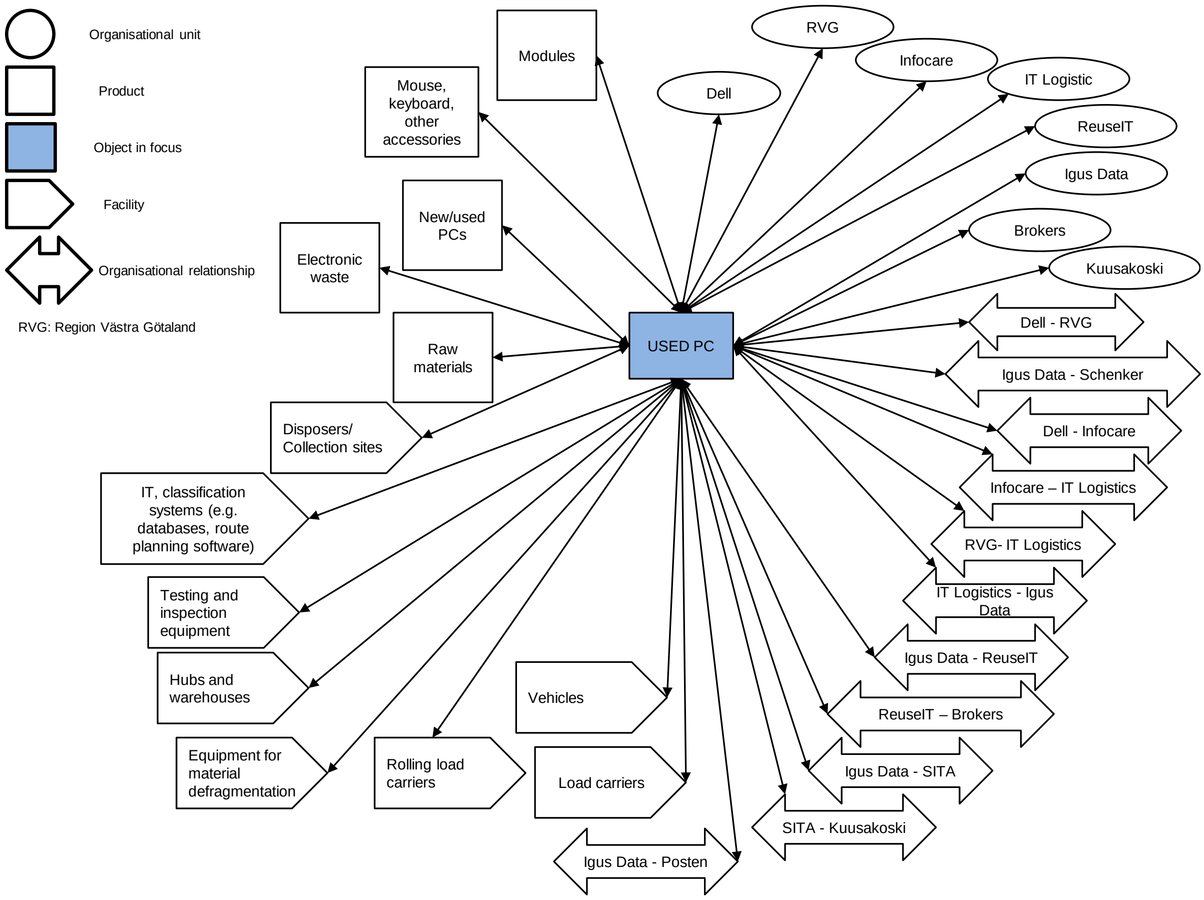

Figure 7.5 Overview of analysed resources and their interfaces around a used PC.

Analyses of the object's interfaces with other products, facilities, organisational units, and organisational relationships will be scrutinised in separate sections. First, the object's interfaces with other products will be considered.

7.2.1 The object's interfaces with other products

A PC has several components that must be combined in a certain way to be able to function together. Its applications might include writing, calculating, playing music, sending and receiving mail, and browsing the Internet. The features of the separate modules must fit together in terms of their size, processor speed and other technological specifications to facilitate utilisation of software. Different material combinations are used to decrease the risk of flammability, and to increase stability and solidity. Several dimensions include principles and rules according to which materials and modules must be combined inside of the object to provide the end user – whether primary, secondary or tertiary – with applications for different purposes.

When it comes to recycling in Transvection 7.3, it is important to handle the raw-material content of the PC. Dismantling difficulties can arise from the previous resource combination, which prevented the computer from falling apart on its way to the customer. On the other hand, a modular design, which facilitates postponement of customisation[44] in the forward physical flow, may make it easier to dismantle the article or replace a defective component in Transvections 7.1 and 7.2. In this manner, the modular design of the PC accommodates efficient disassembly of parts with regard to refurbishing and remanufacturing activities. Thus, in the case of replacing parts and modules, resource tensions are lighter than in recycling resource combinations, where the raw materials from the modules have to be extracted.

Therefore, in the case of PC refurbishing in Transvections 7.1 and 7.2, the object will still retain the initial specifications of a finished product (such as the processor speed, capacity, screen size or price), and may be upgraded and passed on to a broker. Alternatively, a used PC that does not conform to the specifications established for refurbishing will be sorted according to sorting rules for recycling into different kinds of raw materials. In resource combining that involves recycling in Transvection 7.3, a PC can in this way become akin to a package containing products such as metals, glass and plastics.

Objects can complement, or be in conflict with, other objects within the reverse, and between the forward and reverse, physical flows. Materials coming from the recycling process in Transvection 7.3 can complement and compete with both virgin and recycled raw materials.

[44] Assembly of demanded modules.

New mice, keyboards, software and accessories can be added to refurbished PCs in Transvections 7.1 and 7.2 at the materials differentiation points. New software may not fit with all features, such as memory, processor speed and other required specifications that must be taken into consideration. This concerns older, refurbished equipment that is sold to secondary end users.

Objects jointly utilise the same facilities – that is, crossing points – which may be handled by the same or different organisational units. Refurbished PCs can be in competition with new and other used PCs sold by ReuseIT and other firms. PCs might also be used as supplements to printers or other IT equipment at the materials differentiation points. Defective and unsalable objects, such as mice and keyboards from Igus Data, may complement each other when SITA arranges for their co-collection from other disposers in order to spread investments and capacity across many products. Throughout collection, inspection and reprocessing, used PCs coming from RVG share the same facilities. The object's interfaces with facilities will be analysed below.

7.2.2 The object's interfaces with facilities

Actors involved in product recovery have tried to adapt different facilities to objects in a way that improves opportunities for resource utilisation. Different features of objects may be more or less important for appropriate resource combining as far as interfaces between objects and facilities are concerned.

Objects have interfaces with collection sites, collection equipment (including vehicles), testing, reprocessing, and redistribution facilities. During the collection of used objects, rolling load carriers are adapted to objects in physical dimensions, as PCs can use the space inside of them efficiently. The specialised load carrier on wheels is adapted for efficient materials handling at the collection sites. Measurements of this load carrier are consistent with those of doors and elevators, enabling PCs to be collected ergonomically and smoothly from the disposer's workplace. In addition, the specialised load carriers on wheels provide for easier handling at hubs, warehouses, testing, and refurbishing facilities in the transvections.

Monitors, mice, keyboards and hard drives need to be combined within the load carriers according to rules that ensure stability and reduce the incidence of damage in all transvections. Therefore, the heaviest objects are placed on the bottom of the load carrier, as they are kept in the same carrier without unloading until they reach Igus Data's testing facility in Växjö. This implies that features of new and used objects influence how they are combined in load carriers and vehicles during transportation. Therefore, space in the vehicles is more fully utilised when the objects are transported in the rolling load carrier. Another form of efficient vehicle utilisation takes place when refurbished objects without any superfluous packaging are tightly packed for redistribution.

Technological development in logistics towards more volume-sensitive modes of transportation (such as trucks with greater power/consumption ratio) have entailed that an object's volume/price ratio has become more cost efficient than its weight/price ratio. For this reason, synchronised delivery of new PCs and collection of used ones without packaging surrounding each and every object reduces transportation costs. This also means that truck fill rates are maximised in both directions.

Testing equipment, based on the sorting and transformation rules with regard to object classes, is strongly related to objects, as these facilities use the features of similar products in the identification of properties of the object being tested. Based on the values of object classes, decisions are made as to whether objects will be recombined with facilities that deliver PCs in almost the same shape as during their use at RVG, or to other combinations that extract raw materials. Refurbished objects can be recombined with new mice and keyboards, software, trucks, boats, warehouses, containers and software. Defective and unsalable objects, as well as all used mice and keyboards, enter resource combinations for recycling in Transvection 7.3.

Electronic waste from the refurbishing facility has interfaces with other waste, which is collected by SITA as they can share crossing points, such as vehicles and warehouses. PC components are combined with load carriers and other facilities, which are adapted to facilities for material defragmentation at Kuusakoski in Transvection 7.3. Electronic waste going to Kuusakoski can come from other disposers of electronic waste besides the objects delivered from Igus Data. As facilities at Kuusakoski are adapted for electronic waste, SITA needs to wait until full loads can be sent to Kuusakoski, which creates certain conflicts due to increased inventory costs.

Objects have interfaces with classification systems, and planning and information exchange systems. Telecommunication infrastructures and computers involved in sending information are used for resource combining.[45] Various information systems are used to facilitate timely resource combining and recombining during collection, reprocessing and redistribution. Replacement of PCs at RVG would be impossible without databases and information systems to trace each article's features in form, time, place and identity dimensions. To be more precise, classification systems, and materials, route, and enterprise planning systems are utilised to register and transmit information about prices, disposers, object specifications, and collection/delivery dates. The integration of information systems between RVG, IT Logistic, Infocare and Igus Data provides a means for information sharing in order to plan resource utilisation. For example, route-planning software supports the quest for full loads during

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[45] This analysis has a deeper focus on the resources that do not require such long-term investments as resources in infrastructure.

collection by grouping pick-up/delivery locations by date and geographical proximity according to object classes, and sorting and transformation rules with regard to time and place.

Resource combining can change features of objects, such as when PCs lose their specifications in terms of processor speed, the amount of memory and other technical features. Then PC is regarded as a source of raw materials, which are charged per kilo of constituent raw materials. Consequently, the structure of information about the object is modified as the object's features change in time, form, place and identity dimensions at the materials differentiation point when various organisational units handle objects in their facilities.

7.2.3 The object's interfaces with organisational units

How RVG as a disposer organises product recovery affects objects with respect to the efficiency of reverse physical flows in all of the analysed transvections. Buying a few standardised models in large quantities at the same time reduces uncertainties and creates economies of scale for reverse logistics service providers, reprocessors and other actors in the network. RVG's information system, which keeps track of each object in the company's possession, is an enabler of this organisation of product recovery. The knowledge and capabilities of organisational units (including those that use the objects) at different levels within RVG influence the coordination of physical flows internally and externally, since these units interact with drivers and managers from IT Logistic.

Dell affects the features of used objects in technical specifications and price, as they determine these features for new objects in Transvections 7.1 and 7.2. In this way, characteristics of new objects have an indirect impact on used ones. Since Dell is responsible for taking care of used objects after the expiration of the leasing agreement, it influences collection as it outsources this stage to Infocare and IT Logistic. Infocare provides planning and coordination through its interaction with Dell, while IT Logistic is concerned with physical handling at facilities such as hubs, trucks and load carriers. IT Logistic is more directly affected by used PCs compared to Infocare, because IT Logistic is more specialised in logistics relating to these objects. The company's regional knowledge and acquaintance with safe and efficient operations with respect to used PCs reduces damage rates and enhances resource utilisation.

Igus Data has an impact on the used PCs due to its capabilities and expertise with respect to how to sort objects according to rules that guide them either to recycling or to new end users in a refurbished shape in Transvections 7.1 and 7.2. In addition, Igus Data knows how to organise internal flows and logistics in its own facility in Växjö, which influences total costs. ReuseIT is competent in the sales and evaluation of objects, which means that objects affect them in this respect. On the other side of ReuseIT are distributors of remanufactured objects, who partially determine resource combinations for recycling or remanufacturing as they channel the information about demanded attributes. Furthermore, these intermediaries can alter the objects by installing software, upgrading components, and adding new mice and keyboards at the materials differentiation points.

Logistics partners, both in the Nordic countries and abroad, that manage shipments from Igus Data have an impact on the logistics costs of objects. It is their competence in combining means of transportation, load carriers and other products that enable physical distribution at a low cost over great distances. For example, Igus Data's wrapping of objects with plastic film on pallets, and/or packing them tightly in boxes without any excessive packaging, may help to increase fill rates at these crossing points. Nevertheless, full loads cannot always be achieved via the dispatch of used PCs alone.

With regard to recycling the resource combination in Transvection 7.3, Kuusakoski's facility for electronic waste is heavily influenced by general electronics as a group of objects, rather than only by used PCs and their components. The facilities and knowledge at Kuusakoski are adapted to the materials that reside in used PCs. As far as SITA is concerned, its expertise on how to sort constituent parts of used PCs is crucial in order to make deliveries and further separation of materials at Kuusakoski economical. For SITA, used PCs generate minimal revenues as they are collected together with other waste. Due to this fact, SITA is marginally affected by used PCs.

There are other organisational units and organisations that have indirect interfaces with used PCs besides those that affected the original design. Some of them are suppliers of software for the identification of object characteristics and data erasure, while other companies, such as manufacturers and distributors, provide new software and components. Organisational units interact with objects, as well as with each other, through organisational relationships. Hence, the object's interfaces with relationships are analysed below.

7.2.4 The object's interfaces with organisational relationships

First of all, in all the described transvections, the relationship between RVG as a buyer and Dell as a seller has an impact on object features. On one side of the deal there is the purchasing organisation, which includes RVG's own technicians, and on the other side of the deal is Dell's sales organisation. Cooperation between RVG and Dell is crucial for timely deliveries of new objects and collection of used ones. Dell outsources the collection of used objects to Infocare and IT Logistic. These two companies have developed a way to structure information in order to decrease uncertainty and improve efficiency of the operations involved in handling used equipment.

Relationships between RVG, Dell, Infocare and IT Logistic are very important for gathering used objects. Over the years they have learned a great deal from experimenting with respect to how to coordinate and adjust activities performed on objects. Interaction between drivers and managers at IT Logistic and exchange coordinators at RVG help to resolve daily disturbances during collection of objects. Adaptations in terms of providing more correct information about the overall state of objects from RVG and changes in time windows have occurred as well. As of the moment of data collection, all used PCs were not collected (nor new ones delivered) at the same point in time from the same division or place. The number of handling and reloading operations could thus be called into question, as these costs have the potential to be reduced.

In order to achieve maximal resource utilisation, Igus Data as a remanufacturer is highly dependent on Infocare's relationship with Dell. Thanks to information exchange via the classification systems developed in collaboration with Dell, Infocare and IT Logistic can plan delivery of objects to Igus Data. IT Logistic and Infocare jointly plan the details of all routes, including costing and selection of the size of the means of transportation. Owing to the fact that information is shared via the classification system in terms of form, time, place and identity object classes and respective values between RVG, Dell, Infocare and IT Logistic, it has become possible for ReuseIT to sell refurbished objects abroad on a 'just in time' basis despite the higher risks. In addition to business relationships with Infocare and IT Logistic, objects have contributed to the continuation of relationships with foreign distributors. On the other hand, relationships with these foreign intermediaries have an impact on objects as they transmit information about demanded properties of used or refurbished objects. Object features thus influence the relationship with respect to their sales and availability.

The relationship between Igus Data and SITA does not entail any kind of closer cooperation, and objects are more affecting the relationship than vice versa. Farther down the network, SITA and Kuusakoski have closer cooperation. For instance, Kuusakoski has instructed SITA on how to categorise and separate parts of used PCs in order to make handling of electronic waste more profitable and more adapted to their resource collection. Furthermore, SITA and Kuusakoski are able to create classification and dismantling techniques when a newer model of used PCs starts to show up in their resource combinations.

In summary, the object and its features influences, and is influenced by, other types of resources in the 4R model. Other products, facilities, organisational units, and organisational relationships have an impact on the object and its features. In various resource constellations used and new objects can be in competition with each other and simultaneously share the same resources and complement each other. Adaptations between facilities, organisational relationships, organisational units, and objects have been created to accommodate resource combining of forward physical flows. Thus, there are interfaces that have been designed by primarily taking into consideration forward flows of objects, which can create tensions in reverse physical flows. Tensions are normally stronger in product recovery arrangements, in comparison with forward physical flows. Hence, adaptations made in production–distribution networks diminish adaptability in product recovery milieus, which is particularly true when companies want to extract materials from different parts of PCs. It is the responsibility of the companies to achieve efficient resource combining in this product recovery arrangement. The role of actors and their relationships is scrutinised in the next part of the chapter.

7.3 Analysis of organising product recovery in the web of actors

The aim with this section is to analyse organising product recovery in the web of actors. The starting point is RVG in its role as a disposer. The web of actors related to the part of Transvection 7.3 from Boliden Rönnskär to the manufacturer of the copper wire rod has already been scrutinised in section 5.3.

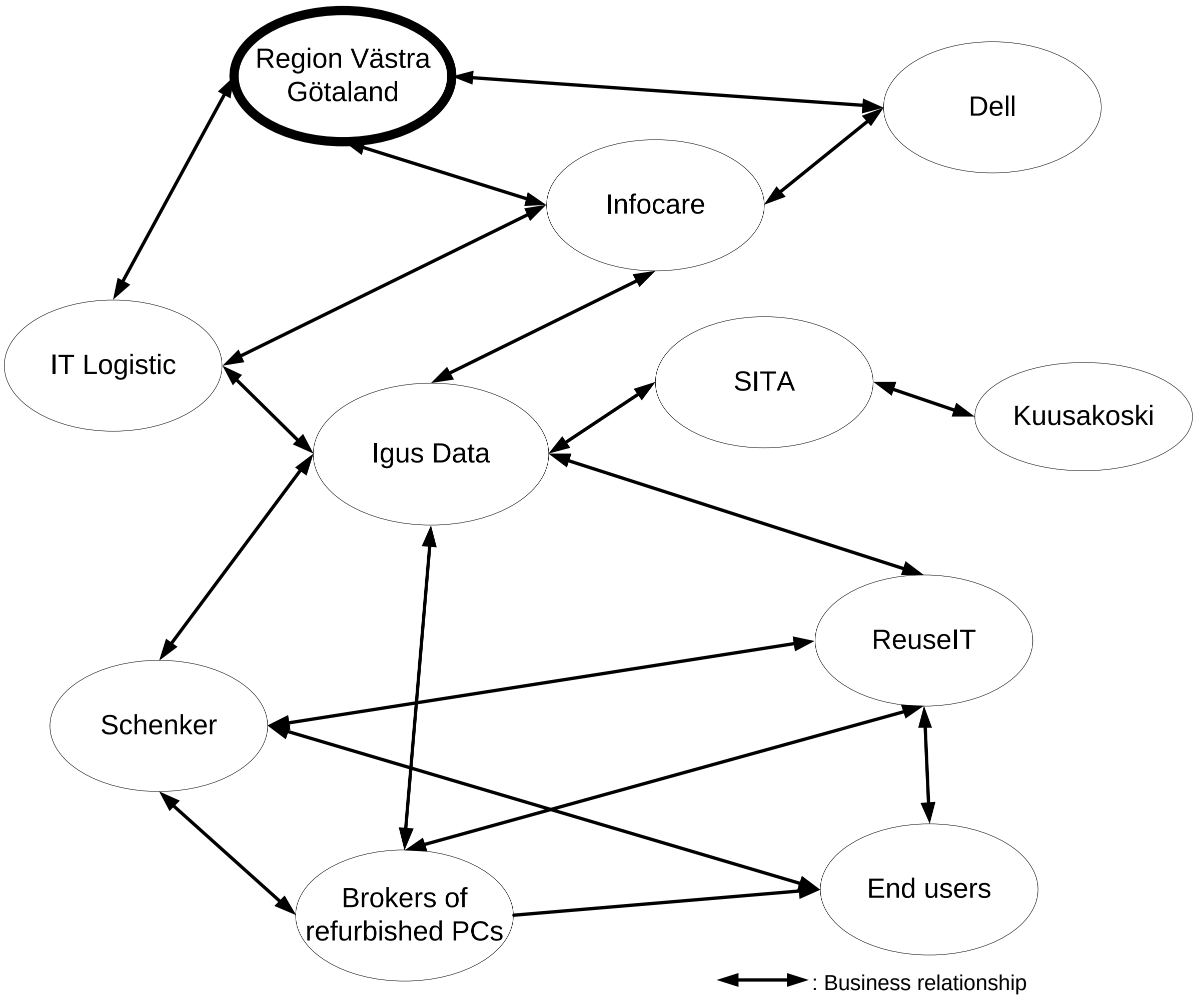

Figure 7.6 Analysed business relationships in the network surrounding RVG.

Figure 7.6 visualises the network and its inherent business relationships, which are discussed in this section. Therefore, this section starts with an examination of the nature of business relationships, and positioning of actors in the network. Then, information sharing and classification systems between actors in the network will be analysed.

7.3.1 The nature of business relationships and positioning of actors

This section analyses the nature of business relationships in this product recovery setting. Issues related to boundary setting, interaction, joint learning, instructions, rules, and actor positioning are scrutinised.

Within the business relationship between Dell and Infocare, there is interaction between the logistics structure for simultaneous delivery of new PCs and collection of used ones, and the business arrangement of spare-parts distribution. Infocare, which was previously only responsible for repair and maintenance activities with regard to PCs in use at RVG, has taken on the role as one of the main planners of the physical flows between RVG and the remanufacturer, Igus Data. Infocare's knowledge of parts replacement has been supportive in the development of the whole product recovery arrangement. Furthermore, joint learning and accumulation of knowledge about activities and resources involved in the distribution of spare parts to RVG has taken place over a number of years. These arrangements have contributed to effective resource combining and activity coordination of product replacement processes in all the transvections. In other words, there is a dynamic interaction between the high- and low-involvement strategies, since firms may first employ a high-involvement strategy with intensive interaction to construct classification systems in terms of article and order number systems, and then, owing to the standardisation of rules, take a more low-involvement approach when the classification systems become more stabilised. Changes in product features, such as the introduction of new product models or generations by the manufacturers of new products, may again require the actors to rely upon the high-involvement strategy. In addition, Dell takes a more low-involvement approach to relationships with regard to the actors involved in reverse physical flows, but a more high-involvement strategy in terms of the delivery of new products.

From the perspective of Infocare, interaction with RVG and other similar clients in these networks has helped the company to design the present product recovery resource structure with IT Logistic. Specialised load carriers were, for example, developed from those that were used during on-site repair, implying that some elements of the present resource constellation were built upon existing infrastructure. In addition, knowledge about routines involved in spare parts is utilised to improve resource combining and activity coordination during the collection of products from disposers. These and other adjustments were conducted jointly with IT Logistic, who is currently responsible for the collection process of products from RVG. Collection and transportation of used PCs to Igus Data are in turn characterised by strong interdependence with the sales and distribution of refurbished products by ReuseIT to end users and brokers in Transvections 7.1 and 7.2.

With short life cycles and a rapid decline in prices, it is crucial to interact with brokers from Eastern and Southern Europe in order to establish a better match between supply and demand of used products. To date, ReuseIT has demanded payment for refurbished products in advance, due to the increased risks associated with foreign brokers. Through application of modern information technology in its resource collection, for the sake of increased visibility of the object's features the company managed to combine tight coordination of integrated physical flows, and effective handling of risks related to foreign brokers. However, much of the information is still inserted manually into classification systems, and product status in the databases is not updated completely automatically, implying the need for a mixture of low- and high-involvement strategies in this part of the network.

ReuseIT and foreign brokers have established business relationships that display strong activity interdependence and advanced resource adaptations in Transvections 7.1 and 7.2, which is characteristic of the high-involvement strategy. This is an effect of high-involvement relationships on the supply side among Igus Data, IT Logistic, and RVG. Hence, business relationships on the supply side of ReuseIT leverage the lack of trust on the demand side. These relationships therefore put ReuseIT in a more powerful network position with respect to brokers in Eastern and Southern Europe, as ReuseIT determines sales terms where a more low-involvement approach to relationships is put into effect. To conclude, some parts of the network, such as those between the disposers, Infocare, IT Logistic, Igus Data, and ReuseIT, may use high-involvement relationships as a power source over less powerful actors; that is, brokers in Southern and Eastern Europe.

In contrast, the business relationship between Kuusakoski and SITA in Transvection 7.3 involves openness and trust. Inefficiencies in activity coordination and resource combining are mainly attributed to technological constraints, rather than to some kind of opportunistic behaviour in business relationships. Nevertheless, SITA and Kuusakoski jointly and separately develop techniques for manual classification for the sake of resource adaptation between objects and facilities so that machines belonging to recyclers can be run continuously. It is usually Kuusakoski that communicates instructions and knowledge of sorting and transformation rules to SITA on how to disassemble and categorise products, whenever a change in product design occurs or an opportunity in routine improvement is identified. An alteration of sorting rules, and therefore the classes of objects sent to Kuusakoski, increased SITA's profitability at the beginning of the relationship, as some sorting was transferred from Kuusakoski to SITA. The rules and procedures are then utilised to coordinate activities and combine resources on a day-to-day basis. SITA also relies on Kuusakoski to account for a specific weight and price of raw materials, which in turn must be reported to the disposers of electronic waste, implying trust and strong actor bonds between the firms in this inter-organisational relationship.

With regard to industrial waste from Igus Data that is bound for raw materials dismantling and recycling at Kuusakoski, SITA and Igus Data manage resource adaptations and activity adjustments jointly. If electronic waste in Transvection 7.3 from Igus Data was not collected by SITA on a more or less regular basis, these objects would occupy valuable storage space. In addition to this interaction with Igus Data, SITA handles relationships and interactions with many other disposers. Continuous modifications of resource collections belonging to these actors generate continuous changes in their waste composition. These changes need to be handled between the disposers and SITA by adjusting activities and adapting resources. Specialised compartmentalised load carriers are therefore used in order to obtain high fill rates of trucks during collection. In other words, flexibility in activity coordination and resource combining is achieved through an endless process of adaptations in the activity and resource layer of the network. These adjustments are supported by trust and openness in relationships. During certain periods of time, interfaces are altered through a close interaction and high-involvement strategy, whereas other periods of time, when the inter-organisational system for classification of objects become more standardised, display more standardised interfaces and a low-involvement strategy.

Interaction in business relationships on a network level has enabled actors to position themselves through specialisation in their activity structures and resource collections by means of the classification systems. Positioning is managed through the division of labour by means of reference input and output values of object classes, as well as with regard to the object classes themselves. In this manner, actors can coordinate activities and combine resources in a counterpart-specific fashion on their supply and demand side. For example, IT Logistic can hold inventory or perform other logistics activities on behalf of other remanufacturers or brokers. IT Logistic’s partner, Infocare, has relationships with manufacturers of new products in which they perform distinctive operations.

Moreover, the content of mutual adaptations can vary, as one of the partners in a business relationship can be responsible for the majority of adjustments. This situation is observable in relationships between Igus Data and logistics service providers. In their relationship with the large providers such as Schenker, Igus Data adapts to their resource collection of standardised load carriers through the classification systems and Electronic Data Interchange, wherein Schenker provides instructions to the consignors and consignees at the beginning of the business relationship, which is then in a phase of a high-involvement strategy. On the other hand, Igus Data and IT Logistic share the responsibility for resource adaptations in a more mutually oriented way, thanks to their high-involvement relationship.

7.3.2 Information sharing and classification in the network

This case study illustrates that involvement of disposers is of primary importance for the collection program because of their key role in the network as an organiser of their internal stock of IT equipment. Close relationships and intensive interaction between the disposing organisation, reprocessors, and logistics service providers over a longer period of time is valuable from an efficiency point of view.

The actors use a number of fixed, pre-set classes connected to article numbers that describe the differences between objects related to the Aristotelian classification at the information differentiation points; that is, when an order is placed. However, during collection of the used computers, a prototype theory approach is employed as it becomes necessary to rely on the past experience of routinised sorting of time, place, form, and identity classes with regard to object collection by interacting with the disposers.

When it comes to approaches to classification systems, the actors rely on a more topological approach with extendable matrices where the object classes may be added or deleted depending on each actor’s needs, although they use a number of typologies that are firmly determined in time, form, place, price, identity, and quantity dimensions. These dimensions can in turn be described by the object classes of, for example, the Periodic Table of Elements, calendars, price systems, addressing systems, and the International System of Units. In addition, the actors in the network use loosely and tightly coupled object classes. The tightly coupled categories are connected to the form features of the raw materials in the objects, while the loosely coupled object classes are more associated with the time, place, and identity dimensions of products. There are loosely coupled categories in the form dimension of objects such as the software, and parts with their particular properties, which are more easily replaced and changed in Transvections 7.1 and 7.2 than the raw materials in Transvection 7.3.

Collaboration between Dell, RVG, IT Logistic, and Infocare has included the development of the advanced procurement process and classification system for order handling and route planning of regular PC replacement at RVG. The system allows for transmission of exact and sufficient information so that relevant data is received by specialised actors in the network, who then can take appropriate actions. These data are required to define standard routings for which activities can easily be activated or deactivated based on the state of what has to be reprocessed, or the output values of prior processes.

The structure of the classification, rule, measurement, and information systems of (among other things) enterprise planning, and article and order number systems in terms of information about weight, volume, delivery/pick-up address and date, is thus crucial as an aid in the handling of sequential and parallel activity interdependencies between many collection and delivery sites. This coordination of activities in the network is critically dependent on the structuring of information in delivery and pick-up dates and locations, product description, and the logistics specifications of consignors and consignees. Classifying information in form (such as the size of the monitor), time (delivery and collection time), place (such as the delivery address) and identity (including the name of the organisational unit) features enables planning with respect to control on two levels.

On the level of individual organisations involved in the network, each actor tries to control internal resource combining as efficiently and effectively as possible. The second level relates to activity adjustments on the inter-organisational level in the industrial network between disposers, logistics firms such as IT Logistic and Schenker, reprocessors, and intermediaries in the second-hand market (for example, ReuseIT and brokers). Infocare, Igus Data, IT Logistic, ReuseIT, SITA, Kuusakoski and disposers adapt the structure of information to their needs relating to time, place, form, quantity, and identity attributes of objects in all the analysed transvections. This data facilitates actual planning and coordination of collection and reprocessing in interaction between actors in the network, as information between actors has to be exchanged so that resource combining and recombining can be accomplished.

Reduction of uncertainty is facilitated through business classification systems, which must connect resources and activities for every actor in the network. Information is allowed to flow to new buyers of refurbished products even while the product is still at the disposer's site, thereby enabling seamless physical flows of refurbished products. This organisation of information exchange accommodates sharing of information and allows for time lags between physical, information and financial flows. Thus, information becomes exchanged for inventory in Transvection 7.1 as ReuseIT can supply information about products to second-hand brokers, who in turn can order products before they enter remanufacturing facilities at Igus Data. Owing to the fact that the information differentiation point is placed as far upstream as possible in time and place, the actors in the network are able to arrange efficient materials differentiation points and economies of scale at the crossing points.

In a similar vein, ReuseIT tries to balance demand with incoming products by accessing information from their brokers in the network. In this way, information sharing by means of classification and information systems in the network provides a procedure for the estimation of price that should be paid to the disposer for the used product. In turn, SITA tries to leverage heterogeneous demand and supply of waste by interacting with disposers on changes in object features and quantities of objects. Hence, this actor intermediates between supply chains belonging to completely unrelated industries with regard to their product/service offering.

Logistics service providers play an important role in this intermediation as these 'unrelated' transvections share resources for transportation processes, since they adapt the information to their needs in terms of its form, time, place, and identity. The detailed data on form features are of less importance to the providers than to the reprocessors. Crossing points in the form of vehicles, distribution centres, and load carriers owned or controlled by Schenker and Posten are examples of resources that are shared efficiently thanks to the topological and prototype classification of information.

All in all, positioning via interaction is decisive for the dedication, adaptation and boundary setting of resources and activities towards surrounding actors. Resource sharing and separation of activities between competitors, partners, suppliers, and customers is essential for capacity utilisation. Business relationship management is characterised by both low- and high-involvement approaches, and relationships can be in various stages of these approaches. Actors use a range of classification systems and principles that are situation-specific. The prototype theory approach to classification is utilised in routines since it is in this case essential to rely on experience of previously performed sortings. Aristotelian and typological classification are applied when there is a need to differentiate objects from each other in terms of classes associated with form, time, place, identity, and price. Within these classes information can be further divided into an extendable number of sub-classes, as in topological classification.

7.4 Summary of the case analysis

The analysis of the activity layer in the network covered activity complementarities and similarities, highlighting sequential and parallel interdependencies between logistics and recovery processes such as refurbishing or recycling. These activities are coordinated jointly by a number of actors in order to handle simultaneous delivery of new products and collection of used ones. The activity interdependencies across firm boundaries have to be handled via cooperation between actors.

The objects disposed of from RVG display uniformity in form and time dimensions but are more differentiated in place and identity dimensions at the disposer's site, as the two actors are located in different areas of the region. Close interaction and collaboration between actors creates an opportunity to remanufacture to order, as detailed information about objects is transferred prior to their physical delivery to the testing facility. This enables the objects to be selected by intermediaries in the second-hand market prior to their disposal and refurbishing in accordance with the principle of postponement. In this case, activities are closely complementary from the disposer to the new end user. However, it is not possible to sell all objects before they enter the inventory at Igus Data. Some used PCs are therefore refurbished in line with the principle of speculation, for the sake of economies of scale; that is, parallel activity interdependencies and activity similarities at the crossing points. This means that activities are complementary between the disposer and Igus Data, and closely complementary from here when the secondary end user selects the object at the information differentiation point. In summary, it is important to handle parallel and sequential dependencies among activities in order to bridge time, place, quantity, and form discrepancies and to balance diversity related to actor-specific adjustments and similarities at the crossing points.

Collection, logistics, reprocessing and redistribution are performed according to rules for sorting and transformation of the classification systems, which are supported by classes that describe each object's form, time, place, price, quantity, and identity. Sorting rules in transvections steer objects at the materials differentiation points towards appropriate resource combinations with respect to the various product recovery processes at the level of parts, whole products, or raw materials. Information about objects and their features change as objects interact with other products, organisational units, and organisational relationships in the network. Some resource combinations with regard to reprocessing alternatives display varying levels of adaptations and tensions, depending on the degree of detachment from forward physical flows for which they were designed. The greatest level of detachment is between resource combinations for recycling and logistics of new products.

Since the beginning of the RVG–Dell project several years ago, the companies have become experienced in working with each other. The resource constellations and activity pattern of the network have been developed gradually during interaction processes. The network strategy has developed from a high-involvement to a more low-involvement one as the interfaces have become more standardised. Hence, what may appear on the surface as a low-involvement relationship culd be the result of close and intensive interaction, during the phase of the high-involvement relationship approach.

Finally, actors need to position themselves so as to handle risks in relationships that are characterised by low levels of trust. In this case study, a refurbishing company exploits relationships on its supply side to leverage the lack of trust on the demand side. Thus application of a more high-involvement strategy on one side of the network can be used to leverage a more low-involvement strategy in the other part of the network. Nevertheless, it is illustrated that lack of trust between the remanufacturer and intermediaries involved in the distribution of refurbished equipment can create a higher risk of unnecessary inventory costs.

The network in this case study enhances economies of scale for many actors involved in product recovery because organisations share detailed information. This information is used in the planning of internal and inter-organisational operations. Depending on the need for information in terms of its quality and quantity, actors use Aristotelian, prototype, typological, and topological approaches to their classification systems, enterprise and materials planning systems, as well as their order and article-number systems. Prototype classification is used to find classes that can be used in a routinised manner, as it is dependent on resemblance between objects and their activity coordination and resource combining. Aristotelian and typological approaches are crucial in establishing differences between objects by, for example, unique article numbers that elucidate form, time, place, identity, and price features of each object. Within this limited number of classes, topological classification with an extendable number of sub-classes can be used. These systems are actor, relationship, and network specific, while at the same time being combined with the general classification systems. Transvection 7.3 is more related to tightly coupled categories of objects, since recycling implies the extraction of raw materials from computers, which is more costly and time-consuming compared to the remanufacturing processes in Transvections 7.1 and 7.2, where loosely coupled categories are present.

8 DISCUSSION

The discussion conducted in this chapter relates to the main results of the analysis. These results are scrutinised in separate sections associated with the activity, resource, and actor layers of business networks. In the last section, the impact of classification systems on all three network layers is elaborated upon.

8.1 Organising product recovery – a network perspective

This chapter deals with the outcomes of the analysis. The analysis was performed using the framework that was developed in the second chapter of this thesis. The research issues, which were posed by means of the framework, are also discussed here. These issues concern all three layers of the Industrial Network Approach, and the influence of classification systems on organising in activity patterns, resource constellations, and actor webs.

On the basis of the results and analysis of the case studies, five theoretical topics deserve a more detailed concluding discussion. The first issue, which is related to activity coordination, relates to the role of the principles of postponement and speculation, and activity interdependencies in the sorting and transformation of objects to be recovered. The second deals with the impact of resource combining on the product recovery network. The third topic concerns the actor interaction between organisations, the nature of business relationships, and information exchange in the web of actors. Hence, in addition to an in-depth analysis of activity structures, the Industrial Network Approach provides a means to comprehend effects that are particularly associated with the resource and actor dimension of the ARA model in relation to organising product recovery. The application of the transvection to the organising of product recovery networks is the fourth theoretical focus area of this chapter. The fifth issue centres on classifications and sorting rules, which proved to be very influential in determining the direction of the objects throughout the network. These concerns are now discussed in separate sections.

8.2 Activity coordination in product recovery

In the *activity layer* of networks, the principles of postponement and speculation, the concepts of activity similarities (parallel interdependence), and activity complementarities (sequential interdependence) are as essential in organising efforts between companies within product recovery milieus, as in supply and production–distribution networks. The first part of this section deals with application of the principles of postponement and speculation in relation to associated strategies developed by Pagh and Cooper (1998), and Wikner and Tang (2008) with respect to product recovery networks, while the second part considers complementarities and similarities between activities. This section ends with a discussion about crossing and differentiation points.

8.2.1 Principles of postponement and speculation in product recovery

The actors use both a full speculation strategy and a full postponement strategy. As shown above, within a *full postponement* strategy changes in form, time, place, and identity are delayed until an end user orders the product. In reverse physical flows, this implies that collection, reprocessing, and redistribution of objects to new end users are postponed. *A full speculation* strategy in planning of product recovery means that the recovered product is physically delivered to an intermediary, such as a broker that is closest to the final customer in the network, so that this end user is served by this decentralized stock.

As this study demonstrates, within a *reprocessing postponement* strategy, postponement occurs in form in terms of the product recovery options. Moreover, reprocessing postponement entails postponement of redistribution to the end user with respect to the change in the object's identity dimension. *Redistribution postponement* refers to a delay to differentiation in time and place. Inventory holding is closely associated with the postponement in time, while transportation is related to the postponement in place.

When it comes to alternative product recovery options, the postponement strategy is more common in remanufacturing and refurbishing, while the full speculation strategy is more frequent in recycling, incineration, and landfill. This is strongly connected to the sales life cycle and perishability of products. Hence, highly perishable products and products that are close to the end of their sales life cycle, such as used desktops or laptops, need to be remanufactured or refurbished as quickly as possible via "shorter" transvection. The refurbishing companies and logistics service providers achieve economies of scale in collection, inspection and reprocessing because reprocessing is performed on both "make to order" and "make to stock" principles simultaneously. More precisely, if the customer order is placed before reprocessing then these objects are recycled or refurbished to order. On the other hand, when the objects are remanufactured to stock – that is, when the customer order is placed after reprocessing – they sometimes need to be transhipped between the actors (such as competing refurbishing companies), which could be at the same level in the product recovery network. This increases both economic and environmental costs, as the transvection becomes "longer" and the object takes a "detour" until it reaches a new end user.

The raw materials of a product that is unsalable in the present form can be processed via a "longer" transvection involving recycling. The risk of obsolescence of raw materials is lower here than in remanufacturing or refurbishing, since the materials can be differentiated in form in a vast number of final products. The fact that recycling and manufacturing of the raw materials requires large investments in reprocessing and manufacturing facilities that necessitate full capacity utilization and the avoidance of production downtime also creates a favourable breeding ground for a speculation-oriented strategy. The special knowledge and highly restrictive economies of scale in recycling, in terms of full exploitation of activity similarities, require centralised reprocessing. All of these issues make speculation less costly than postponement with regard to the risks and inventory holding. The speculation strategy implies the full achievement of economies of scale, since reprocessing and logistics take place in large lot sizes.

The conclusion is that the principles of postponement and speculation, which were developed in order to analyse situations in which uncertainty and flexibility have to be managed concurrently, are appropriate for analytical descriptions of temporal aspects with regard to organising activity patterns in product recovery settings. However, in contrast to the model suggested by Pagh and Cooper (1998), which was developed for forward physical flows per se, and where postponement is coupled with a centralised stock from which the products made to order are delivered, this thesis displays a decentralised structure regardless of the strategy in force. This is related to the final local customer adjustments, which are carried out at the site of the broker. On the other hand, and in agreement with the conclusions of Pagh and Cooper (1998) and Alderson (1950), a postponement strategy often entails the reduction of inventory costs, especially with regard to the reprocessing inventory, which includes a decrease in the risk of holding a stock of unsalable products. It seems that redistribution economies of scale are maintained because the third party logistics providers are able to consolidate physical flows from other consignors and consignees in a cost-efficient manner.

In their role as the primary end users and disposers of the IT equipment, organisations can be regarded as facilitators of a costless inventory space of a generic but uniform product from the perspective of product recovery firms. This means that the diversity of products that are handled and stocked by the reprocessors and intermediaries in anticipation of a customer order can be lowered. These objects can then be differentiated with respect to the demand for the used items. This means that the number of necessary stock-keeping units can be reduced throughout the transvections of a product recovery network. From the viewpoint of the refurbishing firms, the uniformity on the supply side is coupled with simplification of the inventory planning and management, and purchasing orders. Nevertheless, separation of reprocessing and assembly operations steps between various firms leads to the need for coordination among actors and a lack of economies of scale due to decreased activity similarities, which may have a negative impact on the total costs.

8.2.2 Activity interdependencies in product recovery

When they coordinate activities, the actors who organise product recovery manage both the employment of activity similarities and parallel interdependencies, and activity complementarities. This thesis demonstrates that coordination of product recovery activities involves a balancing act between managing activity complementarities and similarities. The advantages of similarities are coupled with the dissipation of economies of scale caused by activity complementarities.

In this way, disposal, collection, alternative product recovery options in terms of recycling or remanufacturing, and distribution are sequentially interdependent. One of the findings of this study is that even product recovery options create waste and by-products, so that some objects that turn out not to be possible to remanufacture have to be recycled. For instance, parallel dependence and activity similarities in product recovery can include the use of the same testing equipment, refurbishing capabilities, transportation facilities and inventories. In addition, actors jointly organise product recovery through the management of both parallel and sequential dependencies between collection, product recovery options and distribution in order to bridge form, time, place, identity, and quantity discrepancies between disposers and actors that utilise these objects either for reprocessing or novel use.

This thesis has shown that activity similarities and complementarities can be used in combination with the concept of transvections for the investigation of economies of scale and customisation of product recovery processes. The transvection analysis is an important supplementary tool for the study of product recovery processes and activities with regard to previously conducted research on these issues.

The essence of activity coordination with respect to organising transvections in product recovery arrangements lies in the handling of activity similarities and complementarities of sorts and transformations in transvections. Sorts are central for the coordination of serial interdependencies among transformation activities. Whether activities are complementary or closely complementary depends on where and when in the activity pattern they become driven by an order from an end user. Thus, if there is no order from an end user, only complementarity between reprocessing and redistributing firms can be established. This is achieved via identification of an object’s properties so that the appropriate actor can perform either recycling or remanufacturing.

Moreover, the organisation of activities in transvections in time has been depicted through application of the principles of postponement and speculation. Postponement of all activities until a purchasing or collection order is received would mean that activities would not be performed as efficiently as possible with regard to activity similarities. Therefore, the principle of speculation generates activity similarities and serves as a complement to the principle of postponement. The extent of activity similarities in, for example, place transformations determines whether a direct transportation will be used. In a similar vein, economies of scale in inventory holding (time transformation) and reprocessing (form transformation) would not be achieved if only activity complementarities were taken into consideration.

8.2.3 Crossing and differentiation points

Concerning the theoretical implications, this study demonstrates that crossing and differentiation points are useful for the theoretical description and analysis of organising product recovery with regard to various object paths toward the end users and the exploitation of economies of scale in collection and reprocessing. This is also valid in relation to supply and production–distribution networks.

Crossing points

This study shows that crossing points can be more associated with uniformities in some, rather than all, object classes and attributes for the sake of scale-efficient transformations. Once the likenesses among object classes, and values attached to these classes, are identified and determined, the quantity of similar objects becomes central to attaining economies of scale in sorts and transformations by applying sorting and transformation rules.

As demonstrated in this thesis, crossing points are important in bridging various discrepancies between the use and reprocessing contexts. A load carrier of dissimilar objects in the form dimension, such as a large truck, is a crossing point that bridges time and place discrepancies at a lower cost per unit of weight or volume over a longer distance. Nonetheless, if a shipment is too small for direct distribution, it goes through a crossing point in the form of a hub, where it is jointly assigned to other objects. Inventory holding of various objects is primarily related to crossing points in time. Crossing points in form refer to remanufacturing, testing, and feature identification of objects performed by the machinery or labour, implying the use of identical knowledge on the objects of the comparable type. In this case, almost identical objects have to be transformed in form jointly, which means that there is a high level of uniformity in form.

Furthermore, the analysis of crossing points is dependent on the aggregation level of the network. For example, pallets are crossing points on their own, which can be grouped into larger crossing points such as trucks or warehouses. Therefore, parallel interdependencies of several crossing points can be grouped together on the level of an entire production or transportation facility, even when the creation of uniformity in the crossing point is present at the level of a single consignment.

Once the uniformity among objects in time, form, place, price, and identity classes is known, these objects can be treated equally, as in routine activities. For example, a standardised load carrier, which has a fixed transportation cost and is sent from one location/consignor and point in time, can be grouped together with other standardised load carriers that are going to the same destination and are to be delivered at the same time. From the activity viewpoint, this implies that actors can organise processes by applying the ‘just in time’ principle, and can handle activity similarities and complementarities, as well as parallel and sequential interdependencies, in an efficient and effective way. The crossing points serve to bridge the time, form, place, and identity gaps in a scale-efficient manner when all dimensions except for quantity considerations are determined at the materials differentiation and/or information differentiation points.

Differentiation points

The implementation of postponement and speculation strategies is much more dependent on the placement of the information differentiation point and accurate and actor-specific information sharing than on a pre-planned localisation of centralised or decentralised inventories. Therefore, it is the point in time and place at which the customer order is placed that largely determines the features of the activity structure of the network. Given enough time to organise the processes with regard to delivery time, the companies are able to exploit the economies of scale in activity similarities and parallel interdependencies, and postpone closely complementary activities in a 'reprocess to order' system. For example, an object can be sold while it is still on the way to a refurbishing facility. Final customisation at the sites of local brokers requires special knowledge in terms of the customer-specific adaptation, which necessitates postponement of the end stages of reprocessing.

At the information differentiation point, an object is assigned by a seller and selected by an end user if there is a match between supplied and demanded object characteristics. At the materials differentiation point, the object's complementarity or close complementarity toward an actor's identity is identified, as it is here that the actual physical properties of an object are revealed.

Differentiation points are crucial in organising of transvections, since it is at these points that activities become closely complementary and objects are assigned to other actors, and eventually to end users. Materials differentiation points that are distributed throughout the transvections are used to identify complementarity and close complementarity among activities in identity, form, time, place and quantity dimensions, as in alternative product recovery options that are undertaken on a large scale. Crossing and differentiation points are analytical tools that serve as enablers of the analysis of interconnections between various transvections of product recovery arrangements. Crossing points are central in identifying uniformities among objects for the sake of application of economies of scale, while differentiation points are related to decisions when objects are assigned to the identity of an actor.

8.3 Resource combining in product recovery

When it comes to the *resource layer*, organising product recovery in terms of resource combining and utilisation is affected by the degree of resource adaptations. The sorting and transformation of an object is studied with respect to its interfaces with facilities, other products, organisational units, and organisational relationships, which is the resource classification employed in the 4R model. The nature of the interfaces, and their consequences for the transformation of an object, are influenced by the combining of resources in the product recovery network. The application of the 4R model on resource constellations in product recovery arrangements shows that developed cooperation and resource adaptations between disposers, logistics service providers, and reprocessors facilitate the efficient use of reprocessing, testing and redistribution equipment. Furthermore, as stated above, the analysis of resource interaction, resource interfaces, and classification systems between objects, facilities, organisational units, and organisational relationships provides a complementary view on product recovery.

The analysis of the resource layer shows how facilities have been adapted to enhance efficiency and effectiveness in product recovery. Large advantages can be obtained when logistics facilities, such as vehicles and warehouses, are adapted to the properties of materials handling equipment and load carriers. Another example of resource adaptation concerns the adaptation of materials handling equipment in relation to the products that are recovered. The design of the product itself plays a crucial role in how product recovery can be organised with regard to resource adaptations. For instance, modular design creates great opportunities for the efficient performance of product recovery options. In agreement with the conclusions of Mathieux et al. (2008) and Mutha and Pokharal (2009), disassembly of products is more efficiently carried out when this aspect has been incorporated in the product development and design phase of a product’s life.

With regard to product recovery options, resource combinations might be characterised by varying levels of tension. The adaptations made in forward physical flows and associated resource constellations are sometimes inappropriate for resource combining in recycling operations. Since recycling demands extensive reprocessing and manual sorting, the tensions in these resource constellations are stronger than in remanufacturing, refurbishing or repair. After all, it is more troublesome to extract the raw materials from the products than to replace modules and components.

Apart from these tensions, there are situations when the new and reprocessed objects can both supplement and compete with each other. Thus, for example, the overall lack of the raw materials increases the competition for supply between the mined concentrate and the recyclable waste, since both of these materials are used in the manufacturing of new goods. On the other hand, the refurbished objects can be complemented with newly manufactured accessories. The 4R model highlights the resource tensions and adaptations, which are not as visible as when the main focus is on the processes alone. Moreover, the results of the employment of the 4R model in this thesis captures the complexities that arise when the forward and reverse physical flows are scrutinised in an integrated fashion.

This thesis demonstrates that the efficient and effective resource combining that is applied in collection, transportation, product recovery options, and redistribution to end users is of great importance for product recovery performance. In collection and recovery logistics, sorting rules were shown to be crucial for resource utilisation, as they direct objects to distinctive transformation resources. In classification, they are crucial for the choice of recovery option. All in all, sorting rules influence which transformations the products will undergo, in time, place, identity, price, and form through classification systems. Resources for sorting are, among other things, different article/order and materials/enterprise planning systems, knowledge of organisational units, and databases. These systems are the basis for the development of sorting and transformation rules, which serve as guidelines for the direction of objects in resource constellations. Since the IT equipment has short innovation cycles, adjustments to the qualitative and quantitative reference values belonging to the time, form, place, identity, price, and quantity object classes have to be made continuously between the actors in the network. Combining and recombining resources changes the features of objects in product recovery arrangements, as well as the information structure that supports the physical part of the combining efforts. The objects keep their original attributes when they are disposed of during remanufacturing and refurbishing, and lose these features when they become a source of raw materials charged per kilo during recycling.

As shown in this study, modern information technology as a resource enables tight coordination of physical flows, and effective risk and uncertainty management between organisations. This occurs when information about object features is adapted and made visible throughout the resource constellations. Adaptations of the resources in terms of classification and information systems between actors enable exchange of accurate information. This data contains the available quantities of load carriers, collection/delivery dates, and geographical locations of objects, which ensures efficient direction of the physical flows and capacity utilisation.

The application of classification systems to product recovery networks in general, and to resource constellations in particular, also represents a theoretical contribution of this thesis to product recovery research. The analysis of classification systems provides an opportunity to examine the influence of information systems. These systems play a crucial role in planning of resource capacity and actual utilisation of a firm’s or a network’s resources, since they reduce uncertainty. Without advanced systems for the exchange of information, it would be difficult to manage the physical flows and steer the objects to adequate transformation and sorting facilities, which was one of the conclusions derived by Ketzenberg et al. (2006). The uncertainty reduction enhances planning and accurate information exchange with respect to resource combining.

8.4 Actor interaction in product recovery

The actor layer of the Industrial Network Approach provides an additional perspective on organising product recovery, as the role of actors is to coordinate activities and combine resources. The organising in networks has been defined in this thesis as inter-organisational activity coordination and resource combining. This study shows that firms that are dealing with product recovery are interconnected through business relationships. The concepts related to the actor layer, such as the level of involvement, can capture the impact of interaction processes on organising product recovery. The roles of the nature of business relationships, actor positioning, and information exchange in organising efforts are discussed below.

8.4.1 The nature of business relationships and actor positioning

Networks of product recovery operations involve organisational relationships between several specialised actors. It has been demonstrated that the nature of business relationships and the positioning of actors have an impact on the performance of product recovery. This issue is further scrutinised in this section. In addition, the exploration of the business relationships and actor positioning contribute to an understanding of the organising of these actor webs with regard to competitive and collaborative behaviours between the actors.

This study supports the findings of Yang et al. (2013), Flygansvaer et al. (2008) and Östlin et al. (2008), who argued that organising principles in a system or a business relationship affect the functioning of the activity coordination and resource combining. Actors have differentiated approaches toward their partners on the supply and demand sides with regard to intensity of interaction. Even the weaker relationships in terms of interaction frequency can be essential in order to balance supply and demand. Therefore, business relationships with varying levels of interaction and involvement enable supply and demand to be matched in networks dealing with product recovery.

In line with the analysis of Gadde et al. (2010), some parts of the analysed product recovery networks are organised according to the principles of high-involvement relationships, with intense interaction between the actors, whereas other parts of the network can be characterised by low-involvement relationships and standardised interfaces and classification systems. Moreover, individual firms can use the high-involvement relationship strategy in their supply or demand base as a power source in dictating the rules and terms of trade in the business relationship to less powerful actors and/or towards those actors whom they do not trust. Nevertheless, the lack of trust increases the risk of unnecessary inventory holding costs.

There is a dynamic relation between the high-involvement and low-involvement relationship approaches. Improvement and creation of new routinised resource combining and activity coordination, which is characteristic of a low-involvement strategy, requires actors in a business relationship to rely upon a more high-involvement approach. Although certain webs of actors may be organised according to the principles of the low-involvement relationship strategy in terms of the standardised interfaces, and thus classification systems, these business relationships could be an offspring of the high-involvement relationships. The development of relationships can lead to routinised interaction procedures as transaction handling becomes more organised. After a period of learning and/or teaching from a point of departure in a low-involvement strategy, the actors in the high-involvement relationship can routinise their interaction through standardised interfaces and classification systems so that the relationship appears to be in the stage of low-involvement again. This includes relationships in which the information differentiation point is placed before the materials differentiation point in order to exchange information for inventory in 'just in time' solutions.

When it comes to organisational resources, the capabilities of companies in the product recovery network are a means by which to combine physical resources in an economic and environmentally friendly manner. This thesis shows that the capabilities to manage relationships differ in relation to the technical skills required for the performance of combining products and facilities; this is in line with Miemczyk (2008). The relationship management capabilities have not been extensively studied to date; while previous research has tended to focus on process capabilities, the Industrial Network Approach offers useful concepts and models for the analysis of the management of organisational relationships and networks. Since organisational relationships are regarded as resources in the 4R model, through which the benefits of increased cooperation can be achieved, this analytical tool complements the prevailing conceptualisation of product recovery. One of the few studies to focus on inter-organisational relationships found, on the basis of a survey, that access to the resources of other firms enables effective long-term cooperation in relation to planning and problem solving in product design and the performance of resources employed in product recovery (Olorunniwo and Li, 2010). These findings are confirmed in this thesis.

Organisational relationships enable actors to jointly create and develop sorting and transformation rules, which are used to combine resources in the product recovery network. A chain of sorting and transformation rules based on the objects and their reference values, which are the building blocks of inter- and intra-organisational classification systems, direct the objects in the resource constellations. In this manner, organisational relationships are resources that enable the use of classification systems in order to locate the information differentiation points before the materials differentiation and crossing points occur, so that most of the objects are sold before they arrive at a facility belonging to the selling organisation. Furthermore, organisational relationships make it possible to combine resources on a 'just in time' basis between the actors in the network.

8.4.2 Information exchange

The organising of resources and activities requires information between actors to be exchanged in a suitable way. Therefore, one of the crucial issues with regard to organising product recovery refers to how information exchange between firms should be organised in order to handle uncertainty relating to the complexity, lack, and abundance of information. In this regard, the concept of classification systems makes it possible to analyse information sharing, which facilitates organising product recovery across company boundaries. This network perspective enabled an analysis of information exchange, and its connection to the coordination of forward and reverse physical flows in terms of various product recovery options. Hence, management of uncertainty requires considerable sharing of information between the actors, as well as the development of mechanisms for communication that improve conditions for the coordination of interdependent sorts and transformations, and the combining of physical and organisational resources.

One type of indirect interaction between actors occurs through classification systems. The classification systems on a network level enable actor positioning with regard to object inputs and outputs. Firms agree upon these object classes in a counterpart-specific manner towards their partners on both the supply and demand side. This enhances the organising of product recovery via cooperative resource adaptations, and activity adjustments. This study shows that even when firms are very similar and find themselves in a competitive situation, what some of them regard as waste and by-products is traded between the parties, thanks to rules of the classification system. Therefore, positioning via interaction is crucial for the dedication and boundary-setting of resource combinations and activity structures between firms and their surrounding actors. Classification systems, which include object classes and values that are attached to these classes, make it possible for the actors to specialise in a previously agreed manner. For example, the reprocessors require that their suppliers of electronic waste, used products, and new components meet the stated object tolerances in terms of product features.

The significance of inter-organisational information exchange in organising the matching of heterogeneous supply and demand has been pointed out by Alderson (1965). He claimed that information ranging over these two sets has to be matched before physical activities are performed. In this thesis, it has been illustrated that when information exchange in networks is organised in accordance with economic utilities in terms of time, place, and form, and price, quantity, and identity features, it may serve as a useful aid in inter-organisational handling of uncertainty. Hence, accurate structuring of information that describes time, place, identity, price, quantity, and form characteristics of groups of objects has an impact on organising physical flows.

Collection of used objects, and their reprocessing and redistribution, are performed in line with the sorting and transformation rules, supported by the classes that depict each object's form, time, place, identity, quantity, and price features applied in information exchange. These characteristics are in turn used to develop and formulate instructions and rules that sort the objects towards appropriate facilities and product recovery options, which are under the control of several organisations in the transvections.

The findings of this study show that actors follow working sorting and transformation rules that govern the use and combining of resources, as well as the performance and coordination of activities. These sorting and transformation rules guide the firms in their daily decision routines. The routines are maintained and enforced with sorting and transformation rules. As pointed out by Håkansson et al. (2006), routines are part of interaction, while interactions partly form routines in a relationship. The benefits of routines include the possibility for improvements, as the repetitive activity can be divided into segments that generate specialisation and the development of capabilities within the organisational units. When all the waste in terms of non-functional activities in the routine action has been removed, it is possible to automate and mechanise the routine, making it less labour-intensive and more precise. This issue is especially valid for the manual steps of testing and classification. These semi-routine processes involve situations relating to elements that have not been encountered before. In this case, the actors are given overriding general rules in the form of instructions during information exchange with the firms on either the supply or demand side. The purpose of instructions is to teach actors how to interpret the values with regard to an object's time, place, form, identity, price, and quantity features, which he or she will receive and act upon. In this way, reprocessors are expected to produce output of a desired quality, and expect their suppliers to provide them with objects in the preferred form, which is adapted to their facilities. Since it is impossible to foresee every contingency that could arise, the actors are often given a set of rules or principles to help them decide from several courses of action and options with regard to the choice of transvections.

Interaction between firms in networks is essential for organising product recovery with regard to activity coordination and resource combining. The study showed that complex recovery networks require well-functioning information exchange, which supports the findings of Thierry et al. (1995). Madaan et al. (2012) claimed that decision integration is a crucial factor for ensuring recovery effectiveness. This conclusion is shared by Parlikad et al. (2006), who argued that information sharing is particularly important for decisions about which recovery option to use. According to the vocabulary applied in this study, a main benefit of extended information sharing relates to the sortings and transformations in product recovery. In a similar vein, Toyasaki et al. (2012) analysed the value of information for product recovery and concluded that advanced information systems reduce the time required for classification of goods, and lead to better decisions concerning recovery operations. That is, information systems improve the effectiveness of sorting rules in transvections.

8.5 Transvections in product recovery

A main contribution of this thesis is the application of the concept of transvection to product recovery activities. In other words, in this study the concept of transvection was used in combination with the analytical tools and concepts associated with the activity layer of the Industrial Network Approach in order to investigate organising product recovery processes in networks. In total, eight transvections were described and analysed in order to illuminate various paths that a product takes from the disposer to the use of the recovered product – that is, the actors demanding the recovered products. Therefore, analytical descriptions of transvections were used to visualise the path from disposers to recyclers and manufacturers of the raw materials, and the processes between disposers and end users through remanufacturing and refurbishing.

This study shows that each object and its classes and values have their own unique transvection that undergoes changes associated with alternative product recovery options. Inside each actor's resource collection and activity structure, some classes and values of these object classes are more relevant than others. For example, a recycler needs information about the precise weight of raw materials inside a laptop, while a refurbisher is more interested in the processor speed, the amount of memory or the size of the screen. These features determine the nature of each transvection, since assignments and selections are about handling of object features and the values attached to these features. Furthermore, these characteristics define the boundaries of the actors, as each firm specialises in a limited number of the object classes and values of those classes. For example, after reprocessing some features remain the same, while others are changed. At least, the time dimension is irreversibly changed even in the reprocessing facility, while the possible changes in reference values and object classes related to form by product recovery options are influenced by the actors in the forward supply and distribution networks who determine the prices and properties of "new" objects. The objects with properties that are not in demand need to be scrapped since they cannot be sold to secondary end users, although they could be fully functional.

Transvections effectively describe various ways of handling similarities and complementarities among activities with regard to the principles of postponement, speculation, and direction of objects into alternative product recovery options or end users. The differentiation points in combination with the transvections are particularly useful tools to visualise where and when the decision regarding various product recovery options are taken in order to describe an object's route in the activity pattern, the resource constellation, and the web of actors in the network. Transvectional analysis in combination with information and differentiation points was used to show how to substitute the inventory with information. Thus, when the information differentiation points are placed before the materials differentiation points, the inventory can be reduced since there is no need to speculate in anticipation of the customer order. Crossing points are a useful analytical tool for the examination of how actors handle parallel interdependence and activity similarities between transvections in order to generate economies of scale.

In its original conceptualisation, the transvection captures all activities in the supply chain, from raw materials to end users. One of the theoretical implications of this thesis concerns the perspective of integrated forward and reverse physical flows, which can be framed within the concept of *extended transvections*. Extended transvections are particularly interesting in light of integrated approaches to forward and reverse supply chains, such as Closed Loop Supply Chain Management. In forward physical flows, one of the major discrepancies is between producer stocks and consumer assortments, since a *"product appears in a very different setting at these two levels and may be said to belong to the technology of production at one stage and the technology of use at the other"* (Alderson, 1954, p. 12). In extended transvections, objects currently in use can also be looked upon as intermediate assortments. Disposers maintain inventory of different kinds of products, which are both those in use and held in stock, and those that could be reused in their present form, or as materials, parts and energy. In this way, the study confirms previous claims regarding the importance of integrating forward-directed distribution with reverse logistics (Lee and Dong, 2008; Turissi et al., 2012; Keyvanshokooh et al., 2013). Thus, the real benefits of a transvection approach to product recovery are attained when the end-of-life transvection is coordinated with the activities in the transvection that place new products in the hands of the disposing firm, as in extended transvections.

Therefore, the function of the business network is to find a match between these segments of reverse supply with the corresponding segments of demand. The uniqueness and heterogeneity of reverse supply and demand are dispersed over very wide geographical areas because unwanted items and heterogeneous customer requirements exist at different places. This situation creates discrepancies of assortments in time, place, quantity, form, and identity, which are resolved through the organising of extended transvections in business networks. In a product recovery context, what Alderson (1954) termed "technology of use" must be connected to "technology of production". Another set of activities needs to be organised in order to move the goods from one side of the heterogeneity to the other by capturing parallel and sequential activity interdependencies of extended transvections.

Thus, the viewpoint of secondary end users has been incorporated into the analysis of product recovery by describing how refurbished and remanufactured products come into the hands of this end user. As most research about product recovery has been focused on collection and reprocessing activities, this point of view can contribute to a more thorough understanding of this actor in reverse physical flows. Research in the field of reverse physical flows and related transvections can give consumers (organisation or individual) with different needs and requirements a more significant role in the network.

Two kinds of sequentially interdependent activities define a transvection: transformations and sortings. It has been demonstrated that sortings and transformations are useful for the analysis of product recovery arrangements, since they parsimoniously depict product recovery activities. Recycling, refurbishing, remanufacturing and component retrieval might be regarded as form transformations. For instance, sorting activities were represented in the collection, storage, transportation, testing, inspection, and classification of the objects. Classification systems, with their sorting and transformation rules and instructions, guide sorting decisions. As demonstrated, resources utilised in sorting assign objects to the appropriate facilities for transformations. Therefore, sorting and transformation rules play an important role in organising product recovery from a practical and theoretical perspective.

8.6 Classifications and sorting rules

Classification systems provide means for coordination and interplay among transformations and sortings in directing recovery objects between the various transformation resources. Hazen et al. (2013, p. 246) discussed the variety of parameters that have to be taken into consideration *"to ensure that the chosen disposition policy is the most advantageous"*. In a similar vein, Galbreth and Blackburn (2006) showed the benefits of what they defined as "sorting policies" regarding the specification of what products should be remanufactured and what should be scrapped. Both activity coordination and resource combining require information sharing through classification systems that embed actor-adapted object classes and reference values assigned to these classes in terms of form, time, place, price, quantity, and identity attributes of objects. These object classes allow for the efficient transmission of information between actors. The classes describing each object's features support sorting and transformation rules, which guide the objects through the activity patterns, resource constellations and actor webs of networks.

8.6.1 Classification and information sharing

On the inter-organisational level, close interactions and information sharing between disposers, logistics service providers, reprocessors and other actors in the network enhance opportunities for synchronisation and continuity of flows. In this way, inter-organisational relationships make it possible to handle interdependence between activities in product recovery arrangements. Sharing of detailed product information between disposers and other actors in the network over a relatively longer period of time before the objects are reprocessed creates possibilities for proper organisation of operations inside and between facilities. In other words, the planning allows machines and trucks to achieve sufficient, guaranteed, steady flows of used products so that the investment in these facilities is profitable. Taking this into consideration, the actors try to reduce uncertainty with respect to time, place, and form attributes of objects on the level of the network by controlling transvections. That is to say, these standardised arrangements entail a predetermined set of activities and resource combinations.

Classification systems, with their sorting and transformation rules, object classes, and reference input and output values to the respective activities and resources, are means by which to locate the crossing and differentiation points in time and space. This is done so that a network displays a sound balance of diversity (variety of a particular actor's requirements in terms of object classes) and uniformity (economies of scale).

Adaptation and interlinking of classification systems provide a means for effective information sharing with regard to availability of objects and facilities, such as load carriers, so that resources are utilised efficiently. These include systems of rules and measurements of a more general type, such as the price system, calendars, Incoterms, and the International System of Units, as well as classification systems that are more ad hoc and specific to an organisation, a relationship, a network, or an industry, even though they may be based on the general systems of rules and measurements. Firm-specific classification systems can borrow classes from the general systems of rules and measurements. Examples of more ad hoc classification and information systems are order and article number systems, and industry-wide grading systems for refurbished objects and electronic waste. Route, materials and enterprise planning systems are information systems belonging to organisations in the network.

8.6.2 Classification principles

The analysis shows that actors use various kinds of classification systems and categories depending on their needs to manage physical flows with regard to the various types of classification principles. Prototype classification is used during testing, since the actor compares the used object to the classes and features of a model for which the features have already been stored. This classification plays a significant role in routine product recovery processes, as uniformities among used objects are exploited in activity similarities. Typological classification, as in a limited number of object features, describes a group of objects in time, form, place, identity, price, and quantity classes. Each article number must contain information about these object characteristics. The topological approach used for classification relies on an open-ended structure of unlimited rows and columns that are adaptable to each actor's information needs about an object. This classification takes place within the overriding typological approach with respect to classifications related to the form, time, place, identity, price, and quantity classes of the objects. The content in these six classes varies depending on the needs of each actor. However, Aristotelian classification, which describes objects in terms of exclusive classes, such as unique order numbers, is used at the information differentiation points, and generates inter-organisational boundaries because several object attributes are firmly decided here. Classification systems can be actor, relationship, or network specific. Network-specific classification systems include grading systems with regard to pricing of refurbished objects and raw materials inside of used objects.

The concepts of loosely coupled (short-term) and tightly coupled (durable) categories or object features describe the endurance of certain object characteristics, which can be useful in theoretical analysis of different product recovery options. The object characteristics that are most persistent take the form of energy that is incinerated and the features of the raw materials that can be extracted from the used products. Loosely coupled categories are associated with remanufacturing and refurbishing, such as the replacement of modules with new or improved parts, and therefore the attributes of an object in this state usually have a shorter longevity compared to the raw materials that went into production of the object in the first place.

8.6.3 The impact of classification systems on the network layers

Classification systems, which consist of object classes, qualitative and quantitative values that are given to these classes, and sorting and transformation rules, have a number of functions, which are connected to all three layers of the Industrial Network Approach. Classification systems impact considerably on all three network layers. First, with regard to resources, they are used to register changes in order to create distinctions and uniformity among objects in the time, place, form, price, quantity, and identity features, so as to direct the objects to the appropriate resources for transformation. Second, common object classes provide the means for coordination and synchronisation of activities in extended transvections. Together with the other elements of classification systems they steer the objects in various dimensions, in order to connect “technology of production” to “technology of use”. This takes place as raw materials, components, and products are being continuously reused in different shapes and end products. Finally, in the actor layer, classification systems create boundaries with regard to classification of objects that firms agree to handle in their facilities. In this manner, actors create counterpart-specific boundaries to facilitate cooperation in terms of dedicated and differentiated activities and resources. By doing this, they also try to avoid direct competition, even among very similar competing firms.

Uncertainty is handled in cooperation between the partners in the network via the establishment of object classifications, grades, and associated sorting rules. These rules have to be modified continuously due to technological development, including advances in materials technology or changes in raw materials in products. Cooperation and interaction between actors have contributed to the development of sorting and transformation rules, as they allow actors to learn a lot about each other in a social, economic and technological sense. Thus, relationships between actors enable joint learning and the development of classification systems with rules that can be used as mechanisms for resource combining and recombining between companies. As variety in form attributes of objects requires different types of testing and reprocessing facilities, classification expertise is essential in order to facilitate routine decision-making and activity coordination between the actors that are involved in collection, testing, reprocessing, and distribution.

Activity coordination and classifications

In order to organise the *activity* pattern of product recovery processes, there has to be a structure of effective information classification, as well as rules on how to sort and transform products so as to enable knowledge sharing throughout the network. Sorting and transformation rules accommodate routine decisions that are associated with direction and re-direction of the objects in the network in terms of changes in the object classes handled and the values that can be attached to these classes in time, form, place, identity, quantity, and price. In this manner, sorting and transformation rules, whether qualitative or quantitative, are crucial as they influence similarities and complementarities in the activity structures.

The adoption of modern IT tools and enterprise planning systems will not automatically lead to efficient activities unless the management takes into consideration the decision points where the information is processed (Mason-Jones and Towill, 1999). Adequate organising of information into classes, and placement of information and differentiation points, would result in more stages of a network having unbiased, undistorted, and rich information on the supply and demand conditions. This would lead to an enhancement of the holistic control and planning of each firm in the network. In that case, individual businesses would collect and process supply and demand data from their partners in order to plan their capacity more precisely on their own.

When it comes to information differentiation and crossing points, object classes in time, place, form, identity, quantity, and price are means of information collection and transfer between organisations that enable appropriate resource combining, and activity coordination for the sake of handling parallel and sequential interdependencies. This is especially true for the management and localisation of information differentiation and crossing points so as to achieve economies of scale and suitable object differentiations during application of the principles of postponement and speculation. In information exchange, valorised object classes with regard to form, time, place, price, quantity, and identity serve as boundaries between actors and as interfaces between classification systems and objects. Actors must be able to compare objects according to certain features in order to qualify them as belonging to the same or distinctive groups.

The creation of more or less constant categories that can be valorised and used in sorting and transformation rules implies a degree of stabilisation of the characteristics that are associated with an object. These characteristics explain why an object is in demand and why, being wanted as such, it can be purchased. Therefore, at the information and materials differentiation points, which are located between the actors, the objects have to be described more firmly. This is done to reduce the administrative costs of sorting, although the classification itself is more diverse and ambiguous in reality (Bowker and Star, 1999). Thus, information is superimposed by means of categories such as article and order numbers, into which properties of objects can be structured. In this way, information about objects is adapted and transferred between actors in a simplified and efficient manner.

Resource combining and classifications

Resources in product recovery arrangements are mutually adapted in their interfaces and features by classification systems, with the aim of enhancing productivity related to their utilisation. Rules for sorting consist largely of “if/then” situations related to qualitative and quantitative aspects of objects, and these are stored, or reside in, resources such as machines or human knowledge. There are rules for assigning objects to different resources with respect to qualitative and quantitative factors, such as distance, size of the vehicles and inventories, machines, and other assets. In this way, a combination of sorting and transformation rules and object features provide guidance of objects through facilities, belonging to various organisational units that deal with product recovery activities. Hence, sorting rules are utilised to classify information about objects in order to direct particular items into adequate resource combinations.

When it comes to the product recovery context, a product such as a used or remanufactured copier has interfaces with its components in terms of resistance, quality features and durability. An additional type of interface is reflected in joint utilisation of resources, such as reprocessing plants and smelters. The same used copier can share production or distribution facilities, or investments, with other products. Interfaces between products and facilities may refer to interaction between the size of the product and load carriers (facilities), which ought to be adapted for materials handling and capacity utilisation reasons. Information and classification systems are facilities that can be helpful in selecting suitable means of transport for the product, as well as partly supporting the quest for full loads in terms of grouping the deliveries by common dates and destinations at the crossing points. Relationships with freight forwarders, reprocessing firms and other organisations also have interfaces with load carriers, plants, and products.

A similar analysis of the changing adequacy of classifications was conducted by Bowker and Star (1999), who stated that classifications as interfaces that appear relevant and homogeneous within a given setting can be viewed as forced and heterogeneous outside of that context, as the objects themselves are naturalised differently or similarly depending on the resource collections. It is the classification systems that communicate information on objects across the network of actors through the object classes. Routine combining of resources requires repeatable and similar informational classifications to identify commonalities and differences among objects. The building blocks of classification systems, sorting and transformation rules with qualitative and quantitative reference values, serve to match supply and demand at the interfaces between actors and across the business networks.

Actor interaction and classifications

The coordination of activities and combining of resources through sorting rules is the task of *actors* in business networks. The significance of classification systems in the actor dimension is reflected in the perceived importance of the object attributes by different actors. Uniformities and distinctions among technical properties of items, packages, load carriers and recycling equipment have varying degrees of importance to actors with regard to the desired performance of collection, reprocessing, and redistribution. In addition, the prototype classifications that are industry- or network-related, such as the grading of remanufactured objects or the pricing system, reduce interaction and transaction costs in the long run, since the actors can use the system for evaluation over a longer period of time.

Moreover, classification systems are used to set the boundaries around organisations in the web of actors in terms of object classifications, which, in turn, enhances inter-organisational adaptations between companies that would otherwise be perceived as direct price competitors. This leads to specialisation of actors in the resource and activity layer of the network. Hence, each organisation has its own article and order number system that reflects its resource collection and activity structure in terms of inputs and outputs. From a network perspective, sorting rules, such as grading systems, contribute to reducing uncertainty as these rules decrease excessive transportation and the need for inspection by each actor who deals with the object in some way.

The directives concerning recycling and hazardous waste on the level of the European Union may provide guidance on how to sort and transform objects, but the detailed, valorised facts on each of the object's identity, form, time, quantity, price, and place classes will not be accessible to the regulators in advance. This thesis has not dealt with the political framework and the regulations of the European Union, which were taken as a given, but rather with the inter-organisational interaction, activity coordination and resource combining in transvections by means of classification systems, although these systems could largely be enforced by the national or international legislation. However, the interaction between politically enforced rules and firm-specific rules represent a possible future research area.

Thus, in product recovery the most tightly coupled categories of an object are the characteristics of the raw materials that went into its manufacturing as a new offering. The product sales life cycle reflects in the changes of reference values assigned to the object classes by the actors, which, to a great extent, influences the assignment and selection of objects to distinctive product recovery options – that is, primarily transformations in form. Thus, product development and innovation entail changes of qualities and properties expressed in the classes of products through time. The products themselves are bounded off by their properties (from other objects), which in turn can be categorised by means of standardised systems of rules, measurements, and classifications.

9 CONCLUSIONS AND IMPLICATIONS

The aim of this chapter is to summarise the main conclusions of the thesis. The chapter concludes with the implications for practice and suggestions for future research.

9.1 Framework

The overall purpose of this doctoral thesis was to apply a network perspective to product recovery. The main contribution of this research is the framework that was developed in the second chapter of this monograph. Moreover, a specific aim of this study was to investigate the organising of product recovery networks by applying this framework. This was empirically achieved via an investigation of the organising of product recovery networks in the form of two qualitative case studies; this supplements the mainstream research approaches, which are *"limited almost totally to quantitative research and models"* (Gobbi, 2011, p. 772). Although product recovery involves a number of organisations, it has been stated that interaction and collaboration among these organisations has not been sufficiently explored to date (e.g., Fleischmann et al., 2000; Toffel, 2004; Chan, 2007; Gobbi, 2011; Winter and Knemeyer, 2013).

The theoretical base of the Industrial Network Approach has contributed to an understanding of the phenomenon of organising product recovery from an integrated viewpoint of all three layers of the ARA model through an analysis of the activity pattern, the resource constellation, and the web of actors by applying the multifaceted analytical framework for studying product recovery structures (see Figure 9.1). This framework explores the issues related to the impact of activity coordination, resource combining, actor interaction, and classification systems on product recovery in business networks.

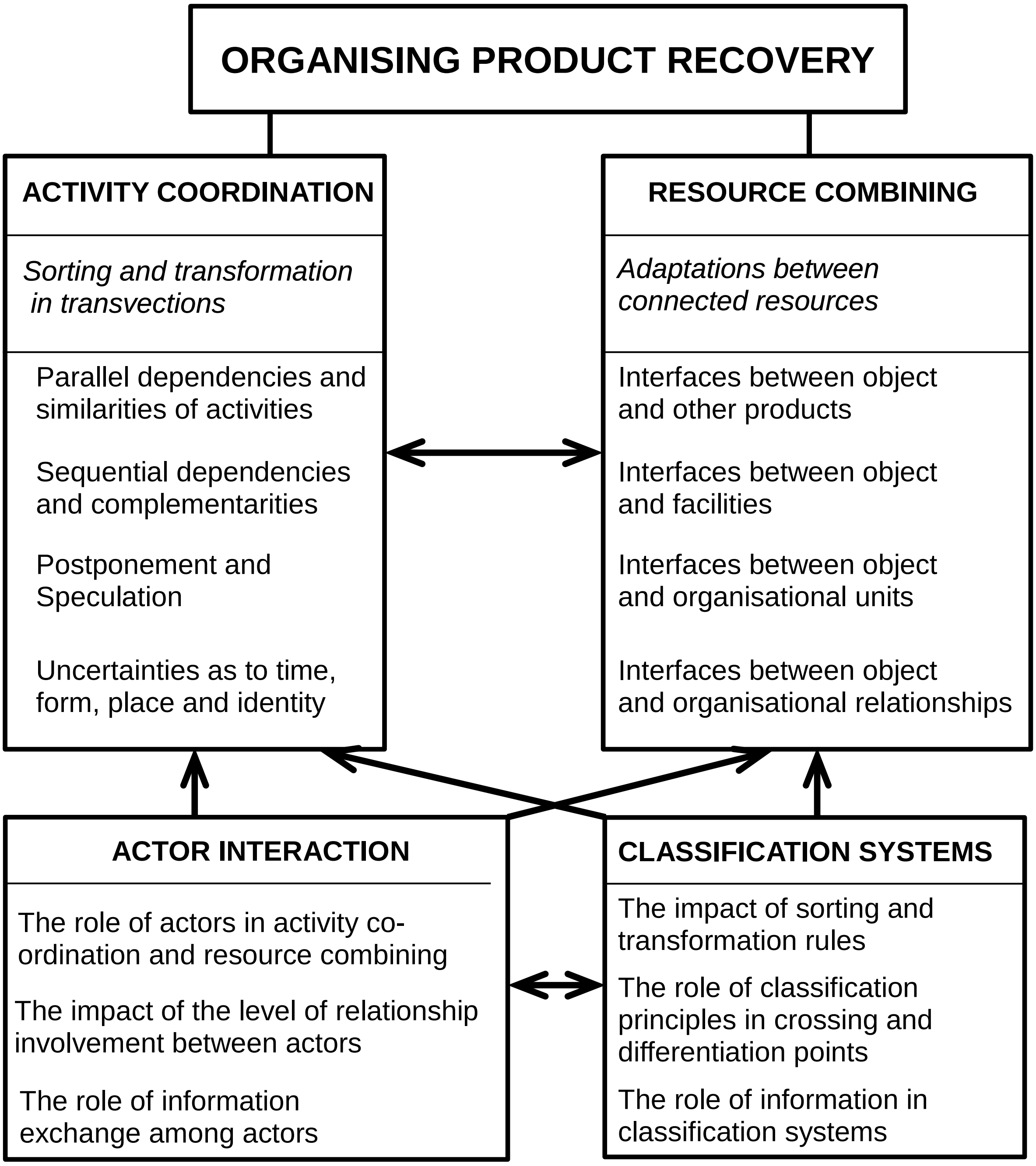

Figure 9.1 A framework for analysing the organising of product recovery.

In addition, although this thesis focused on the primary end users as disposers, the framework developed during the research process can be applied to explore product recovery networks where the producers and actors involved in physical distribution dispose of objects. In other words, the transvections and activities of objects that are disposed of during the production and distribution phases of a product's life can be analysed using the frame of reference outlined in this thesis. This was briefly discussed by Alderson and Martin (1965), who incorporated the costs of waste and by-products in the transvection analysis of an end product, which stretched from the raw materials to the final outcome of a transvection. One of the theoretical contributions of this study relates to the framework based in the analytical tools and models that were developed within the Industrial Network Approach. Apart from analysing the activity pattern, which has been done in previous research, this framework makes it possible to scrutinise organising product recovery in resource and actor layers. In addition, the role of classification systems on organising product recovery was dissected. The main conclusions from the empirical study in relation to the activity, resource, and actor layers, as well as the classification systems and rules, are summarised below.

9.2 Conclusions from the empirical study

The separate analyses of the actor and resource layer of the product recovery network with regard to multiple product recovery options are considered additional theoretical contributions of this thesis, because the research within the area of reverse logistics and Closed Loop Supply Chain Management has been mainly conducted from a process-/activity-based point of view. Most of the frameworks are based on generic descriptions of activities, which include acquisition, collection, transportation, classification, product recovery options, and distribution of products, parts, and raw materials to new end users of the final product, or to intermediate actors who need these objects for production. This study confirms the central role of efficient activities and brings the conceptualisation of product recovery somewhat further. The transvection concept, in combination with analytical tools from the Industrial Network Approach, clarifies the crucial role of interdependencies and adjustments of activities. Activity coordination is further addressed in the next section.

9.2.1 Activity coordination

All product recovery activities have their particular benefits and disadvantages, as analysed in this thesis. Both strengths and weaknesses of current organising of product recovery have been previously studied by academics and researchers. However, the majority of theoretical models and frameworks do not connect the reverse and forward physical flows, since they focus on the management and organising of collection and various product recovery options (e.g., Flygansvaer et al., 2008; Jamshidi, 2011; Krikke et al., 2013; Giovanni and Zaccour, 2014; Guarnieri et al., 2014). In order to be relevant for managers and businesses, by means of the concept of extended transvections, this study provides a framework for the analysis of organising product recovery by applying an integrated perspective, as requested by Guide and van Wassenhove (2009). More precisely, by means of the concept of extended transvections that are embedded in business networks, this thesis integrates the acquisition and collection of used objects, various product recovery options, remarketing of the recovered products and raw materials, and novel use.

Several authors have shown that production, distribution and use are interrelated in business networks, and that boundaries between these processes are blurred (Hulthén, 2002; Håkansson et al., 2009). The network perspective highlights the fact that the activities associated with the phases of a product's life in terms of production, distribution, use, and product recovery are interdependent. Hence, all of these processes should be treated as integrated parts of a total network. This thesis confirms the starting point of the study, which suggested that product recovery operations are interconnected in a network of inter-organisational relationships between a number of various facilities and actors. Business relationships and collaboration between organisations, which have been given minor attention in previous research, are assets that are utilised in these networks for activity coordination.

From the secondary end user's perspective, there is no difference between reverse and forward physical flows. This is owing to the fact that the secondary end users can choose to buy new, or refurbished or remanufactured products. Indeed, end users can buy new products that can be partially or completely made out of recycled raw materials coming from similar or totally different products. From the viewpoint of the overall network, it is argued that product design, manufacturing, forward logistics, and product recovery activities should be treated as integrated parts of a single constellation of firms. This means that both forward and reverse flows of goods and services should be treated and analysed as components of the same network. Inter-organisational relationships and interaction in these networks are central means of efficient and effective organising of product recovery configurations.

The central role of efficiency and effectiveness in activities has been brought further in this thesis. This was done by focusing on the principles of postponement and speculation, and the concepts of activity interdependencies, extended transvections, and crossing and differentiation points.

Principles of postponement and speculation have been adapted to the product recovery networks. The perspective of extended transvections clarifies that disposers are facilitators of costless[46] intermediate stocks of generic, but uniform, objects, which can be differentiated with respect to novel use by the principle of postponement. Postponement strategy is more frequent in remanufacturing than in recycling, since the object here is close to the end of the sales life cycle and needs to be recovered as soon as possible. The risk of obsolescence is lower in recycling, since the raw materials out of which the used objects are made can be used in a large number of final products so that full exploitation of economies of scale can be achieved as reprocessing and redistribution are performed in large lot sizes.

Activity similarities are crucial in economies of scale in crossing points, while activity complementarities are fundamental in customisation of objects in transvections. Close

[46] From the viewpoint of product recovery firms.

complementarity in the activity pattern is determined by the location of the information differentiation point in time and place with regard to the end user. Thus, after an order placement by an end user, the activities become closely complementary. The decisions that establish activity complementarity are made at each assignment whenever this concerns adaptations toward another actor's identity. Given enough time vis-à-vis delivery, for example, the actors are able to balance between activity complementarities and similarities in a postponed "reprocess to order" network. Differentiation points are central in assigning objects to an actor's identity, while crossing points are related to the identification of uniformities between objects in order to utilise economies of scale.

9.2.2 Resource combining

Interaction, adaptation, and utilisation of products, facilities, organisational units, and organisational relationships influence the ways in which resources are efficiently and effectively combined. As previous studies of product recovery have predominantly been conducted from a process viewpoint, the analysis of resource combining, interaction, interfaces, and adaptations provides a supplementary perspective on product recovery. This is especially true for organisational relationships, which are one of the resource entities of the 4R model. Organisational relationships serve as bridges between organisational units, which make it possible to take advantage of long-term cooperation and joint planning of product recovery.

The 4R model enables a combined analysis of integrated forward and reverse physical flows, and visualises the complexities of this integration. For example, when the ease of disassembly among modules has been taken into consideration during product development, disassembly is more efficiently performed in reverse logistics operations. There are resource tensions between new and reprocessed objects when these are competing with each other, while some new and reprocessed objects supplement each other. Resource constellations for recycling can display more tensions than the resource constellations for remanufacturing and refurbishing, as the latter constellations are comparable to those in manufacturing of new products. The object features affect resource combining, and combining of resources changes the object characteristics. The use of facilities in the form of classification and information systems directs the objects throughout the resource collections of several actors. For example, these systems make it possible to select an appropriate mode of transport and to aim for full truck loads.

9.2.3 Actor interaction

It is the actors' job to coordinate activities and combine resources in the network. Business relationships in the network are central to these efforts. Even though the importance of a network perspective on product recovery has been demonstrated in studies of manufacturing networks (Francas and Miller, 2009), logistics networks (Das and Chowdhury, 2012), strategic networks (Mutha and Pokharel, 2009), value recovery networks (Srivastava, 2008) and product recovery systems (Madaan et al., 2012), the majority of these studies have concentrated on a number of isolated and specific issues (Winter and Knemeyer, 2013). Winter and Knemeyer, together with Chan (2007) and Gobbi (2011), advocated a holistic viewpoint on interactive organising product recovery, since the actual scope of research regarding product recovery necessitates going beyond a single focal company's perspective. This must be done in order to include how companies outside of the focal company perceive the constellation of businesses that collaborate in these settings.

This study emphasises the vital role of inter-firm organising in the activity and resource layers of product recovery arrangements. That is to say, there was a minor focus on the inter-organisational constellations and theoretical implications in previous research. This knowledge gap was identified in the first chapter of this thesis, and implies a lack of research centring on cooperation and interaction between organisations. More precisely, business relationships and inter-organisational coordination of activities and combining of resources were pinpointed as research areas that deserved a more theoretical framework for the study of organising product recovery. The framework of this thesis provides an analytical frame of reference for research topics that prior studies (e.g., Winter and Knemeyer, 2013) have asked for, such as the influence of network configurations, the conceptualisation of product recovery processes as integrated parts of a total system, and the impact of actor interaction and cooperation on the performance of product recovery networks.

This thesis shows that product recovery arrangements consist of a large number of firms that are tied together in a network through business relationships. Moreover, it argues that organising product recovery is a complex issue that entails a holistic perspective, as inter-organisational structures influence economic and environmental effects. For that reason, the Industrial Network Approach was applied in this thesis. This theoretical framing makes it possible to analyse interaction among business partners and cooperation between firms, as requested by Winter and Knemeyer (2013) and Fleischmann et al. (2000), since product recovery is *"made up of several independent organisations dealing with different aspects of the system"* (Knemeyer et al., 2002, p. 458). In this study, it was demonstrated that analytical tools and models developed within the Industrial Network Approachresearch tradition related to analysis of activity patterns, resource constellations and actor webs of supply and production-distribution networks are suitable starting points for theoretical treatment of these issues in product recovery.

In order to match supply and demand, organisations in product recovery employ relationship strategies with both high and low levels of involvement and interaction. Inter-organisational cooperation improves the efficiency and effectiveness of activity coordination and resource combining. High-involvement relationships can be used by organisations as power bases, and to leverage the lack of trust in order to dictate the terms of trade and manage the risks associated with less trustworthy partners. Development of relationships can lead to low-involvement situations and standardised interfaces typical of the low-involvement approach, as actors progressively engage in more routinised transaction handling. Furthermore, whenever a need or desire for improvement in routines appears, business relationships can enter into the phase of high-involvement so that enhancements can be carried through.

Uncertainty and risk handling are facilitated by the development of business relationships and information-sharing mechanisms between organisations. The structuring of information in form, time, place, identity, price, and quantity classes supports the management of uncertainty and physical flows. These classes are used to set the boundaries around organisations and to formulate sorting and transformation rules that routinely guide the objects in the activity pattern and resource constellation. Rules such as those of Incoterms maintain and enforce routines intra- and inter-organisationally. Actor positioning by interaction via, among other things, classification systems is central to specialisation and boundary setting in activity and resource layers of product recovery networks.

9.2.4 Classification and organising

Classification is decisive in the direction of objects into appropriate facilities for alternative product recovery options. Classification systems are used to generate boundaries with regard to the object classes that each organisation handles, so that even competitors are able to cooperate. Each organisation is specialised in a limited number of object classes and the reference values attached to these classes. This means that classification systems facilitate matching of supply and demand at the inter-organisational interfaces. The object classes can be borrowed from more general systems of rules and measurements, such as the International System of Units. These classes are embedded into article and order number systems that effectively describe the resource collection and activity structure of an organisation. The article and order number systems are used to identify differences and commonalities among objects by means of sorting and transformation rules. Since they support long-term routines of selections and assignments, classification systems decrease interaction and transaction costs. From the network viewpoint, classification systems, such as grading systems, reduce the need for unnecessary transportation and inspections by every actor who is involved in the physical flow of an object.

Prototype classification applies to the routine identification of uniformities and differences based on the previous classifications, so that each offering is given a unique article/order number by means of Aristotelian classification of a number of exclusive classes at the information differentiation point. Typological classification is used in the description of a fixed number of qualities of an object’s form, time, place, identity, quantity, and price dimensions, which are adaptable to each actor’s needs. Within this typological classification, the topological classification in the form of an extendable and adaptable number of sub-classes takes place. When it comes to loosely coupled (short-term) and tightly coupled (long-term) categories, the most persistent features are the energy and raw materials that went into the production of an object that is recycled, while more short-term characteristics are related to the refurbishing of an object that keeps the specification of the initial final product. Changes in the values attached to the object classes reflect the progression of the product life cycle, and its product development. Therefore, changes in the values of the object classes influence the selection of a product recovery option.

In order to manage risks and uncertainty, and for the sake of appropriate boundary setting, activity coordination and resource combining, each actor has to be notified about supply and demand through adapted information on object classes in terms of form, time, place, identity, price, and quantity characteristics. One of the missions of each actor in the network is thus to transform and adapt information to its partners on both the supply and demand side. This information is transmitted and stored in network-, relationship- and organisation-specific information and classification systems. Sharing of object information by these systems prior to their physical handling creates opportunities for efficient resource utilisation, management of uniformity via, for instance, economies of scale, and diversity in, for example, customer-adapted offerings. Business relationships enable actors to develop, teach, and learn classification systems, with their sorting and transformation rules that steer the objects in the network. In this way, these rules are mechanisms for routine activity coordination and resource combining. Rules for sorting are made up of “if/then” situations (concerning, among other things, the selection of a product recovery option), which reside in machines, software, or human knowledge.

9.3 Implications for practice

Several issues related to the practical implications of organising product recovery have been identified. In accordance with research previously conducted in this field, one of the results of this thesis is that product recovery is frequently associated with uncertainties. For instance, supply uncertainty in the form dimension causes unnecessary transportation and classification. Supply uncertainty is therefore strongly connected to organising product recovery. This uncertainty takes the form of variability in volume or a low level of economies of scale, and variability in quality, as well as labour-intensive selection/disassembly of products, parts and materials. A supplementary variability relates to the type of returned product or the allocation of a product to specialised, dedicated reprocessing facilities.

The uncertainties in timing, volume and the state of product can increase transportation work or inventory maintenance costs if the fill rates are not taken into account. In turn, this can diminish economies of scale of consolidated and centralised flows in remanufacturing and recycling, as well as in transportation. One way to handle this situation so as to reduce uncertainty is to involve the disposers of IT equipment. The structuring of information in accordance with the economic utilities and identity, quantity, and price object features creates the possibility to manage uncertainties. Efficient and effective sorting can be achieved if the disposers use these classes as a point of departure in their interaction with the collection and reprocessing firms. A stable structure of a predetermined number of metrics would increase the number of routine steps in administration.

In order to reduce uncertainty and enhance efficiency, disposers can increase their involvement in integrating forward and reverse physical flows by interacting with the firms that organise product recovery configurations. Increased participation of disposers and enhanced inter-organisational coordination of activities and resource combining between disposers and other actors involved in product recovery could be implemented through high-involvement business relationships. This can lead to structured information exchange through sorting rules that would help to establish routinised activity coordination and resource combining.

Another practical implication concerns collaboration between different parties in the network, such as third party logistics service providers, recycling/remanufacturing firms, intermediaries, and disposers. Extended cooperation can decrease the uncertainties associated with product recovery. Such collaboration reduces the environmental impact, as well as the costs of unnecessary transportation of goods that are suitable for other recovery options than those of the present facility. With greater involvement from disposers and joint planning between remanufacturing companies and logistics service providers, as well as economies of scale and more precise planning of transportation, collection and reprocessing can be achieved. These benefits require consideration of adapted, accurate and sufficient object classes and topologies of interfaces and classification systems in order to avoid intermittent physical flows and unnecessary testing and inspection of objects at each step in the network processes.

There is room for more organised product recovery in terms of integration of forward and reverse physical flows, and structuring of information exchange through enhanced cooperation. As mentioned in Chapter 2, joint investment by several actors in business relationships could lead to the instalment of IT systems for tracking and tracing of used products in real time, instead of scanning and inserting these data manually. In this way, all kinds of relevant data could be collected and utilised when executing activities, and in the planning and monitoring of these processes. This reduces logistics costs and improves customer service as a third party logistics provider collects used units (instead of an employee who uses the equipment) from the workplace and installs new products simultaneously.

Several disposing organisations do not manage their stock of PCs, laptops, and accessories from either the informational or the geographical view of proximity between products in use.

New objects are purchased without taking form, time, and place characteristics of objects into consideration. Unorganised purchasing of new objects in these dimensions by disposers has an influence on the organising product recovery. For instance, the form and time dimension of the objects mirrored in the product sales life cycle determine, to a great extent, the path of the product to a suitable reprocessing facility. This is especially true for returns in the electronics industry, such as PCs, for which the reduction in prices increases toward the end of the sales life cycle. By taking into consideration the perishability, sales life cycle and place dimension of objects, such as geographical location and geographical closeness of different disposing business units (primary end users), firms can facilitate the economic direction and distribution of objects into adequate facilities. In this way, each instance of product replacement would occur in accordance with the product's sales life cycle.

9.4 Further research

This thesis has shown that the concept of transvection can be translated to accommodate reverse flows as types of extended transvections. This is one of the reasons why the costs of various transvections seem appropriate for future studies related to organising product recovery in business networks. Future research involving crossing and differentiation points, principles of postponement, and speculation in extended transvections could provide a thorough investigation of the transportation, inventory holding, and reprocessing costs related to these strategies. Speculation and postponement strategies give rise to possibilities to accomplish cost-efficient and timely physical flows by rearranging reprocessing and redistribution configurations. It would be interesting to analyse data on costs associated with alternative ways of organising product recovery.

When it comes to issues that are specific to the empirical findings of this thesis, there are several topics associated with the principles of postponement and speculation that can be investigated further in future. As in this thesis, the Pagh and Cooper (1998) reference, together with Wikner and Tang (2008), and Abrahamsson (1993), can be used as a basis for further analysis of postponement and speculation strategies in product recovery networks. Since the final customisation of remanufacturing is postponed in the case descriptions of this thesis, a study of the impact of a structure where the remanufacturing is performed centrally could be conducted. One of the future topics would be to investigate the amount of reprocessing activities that could be done in a single facility without losing the ability to adapt towards customer requirements.

The focus of this thesis has been on analysing inter-firm organising of product recovery. In this regard, the Industrial Network Approach could be useful to study interaction between businesses and the government or regulatory bodies. This approach would enable researchers to scrutinise the relationships, and the development of relationships, between the firms and regulators, as well as study the existing classification systems and provide recommendations on the alteration and management of product recovery constellations in particular, and business networks in general.

Crossing and differentiation points as analytical tools would highlight whether the directives and regulations on the national or international level concerning object classes restrict or empower the possibility of firms involved in transvections to obtain economies of scale in the most environmentally friendly way (that is, via a product recovery option). The application of differentiation points to the study of organising product recovery would enable researchers to identify qualities or characteristics that are defined by the regulators, and to highlight which rules and associated classifications are the offspring of inter-organisational relationships or individual firms. In this respect, the concepts of differentiation points will enable an analysis of the points at which regulations influence inter-firm materials and information flows.

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