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Importance of closed-loop supply chain relationships for product remanufacturing

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Abstract

Remanufacturing is an industrial process where used products are restored (remanufactured) to useful life. In comparison to manufacturing, remanufacturing has some general characteristics that complicate the supply chain and production system. For example, a company must collect the used products from the customers, and thus the timing and quality of the used products are usually unknown. Remanufacturing companies are dependent on customers to return used products (cores). In this paper, seven different types of closed-loop relationships for gathering cores for remanufacturing have been identified. The relationships identified are ownership-based, service-contract, direct-order, deposit-based, credit-based, buy-back and voluntary-based relationships. Building theory around these different types of relationships, several disadvantages and advantages are described in the paper. By exploring these relationships, a better understanding can be gained about the management of the closed-loop supply chain and remanufacturing.

Keywords: Product recovery; Reverse logistics; Relationship marketing

1. Introduction

Remanufacturing is an industrial process where worn-out/broken/used products referred to as cores are restored to useful life. During this process, the core passes through a number of remanufacturing operations, e.g. inspection, disassembly, component reprocessing, reassembly, and testing to ensure it meets the desired product standards. This could sometimes mean that the cores need to be upgraded and modernised according to the customer requirements (Seaver, 1994; Lund, 1996; Sundin, 2004).

During the Second World War the remanufacturing industry spawned, especially in the United States since many manufacturers were focusing on military production.

Remanufacturing is still a rather large business in the United States (Lund, 1996), but also in Europe, where the industry has been growing lately due to its profitable business and environmental legislative pressure from the European Union (EU), such as the launching of the Waste of Electric and Electronic Equipment (WEEE) and End of Life Vehicle (ELV) directives. These directives are currently being implemented in the EU member countries in either an “industry collective” or “company individual” manner. From an institutional viewpoint, the effects of these directives can become a significant driver for the remanufacturing industry. How these directives are implemented will have a significant effect on the remanufacturing industry. According to Webster and Mitra (2007) a collective implementation, the specific industry branch are collectively responsible, would make a structural change to the industry—creating an environment where remanufacturing becomes profitable if not already profitable without a take-back law. On the other hand, if these directives are implemented company individually, i.e. each company will be responsible for their own products, the companies will get better control of their own remanufacturing business.

There are various motives for product remanufacturing e.g. increased profitability, ethical responsibility, legislation, secured spare part supply, increased market share and brand protection (Seitz and Peattie, 2004). Furthermore, remanufacturing has also been shown to be environmentally preferable in comparison with other end-of-life treatments, since the geometrical form of the product is retained and its associated economic and environmental values preserved (Sundin, 2004; Bras and Hammond, 1996; Kerr and Ryan, 2001).

Material flows are an important factor for the overall remanufacturing system (Guide, 2000). A traditional view on these closed-loop supply chains is that they encompass two distinct material supply chains: the *forward* and the *reverse*. Generally, the forward chain concerns the flow of physical products from the manufacturer to the customer, while the reverse chain describes the flow of used physical products from the customer, then acting as supplier, to the remanufacturer. These flows are then “closed” by, for example, the remanufacturing operation. One of the major differences between the “forward” and the “closed” supply chain is that the customer frequently acts both as a customer for remanufactured products and as a supplier of cores to the remanufacturing company (Krikke et al., 2004).

Compared to manufacturing, remanufacturing has some general characteristics that complicate the supply chain. For example, a company retrieves used products (a.k.a. cores) from the suppliers of cores, these suppliers are normally the end customers but it can also be scrap yards, core brokers or incurrence companies. As for end customers there is a major difficulty to assess the number and the timing of the returns. Another complicating issue is that the quality of the used products is usually not known (Guide, 2000; van Nunen and Zuidwijk, 2004; Guide and Jayaraman, 2000; Geyer and Jackson, 2004).

For the performance of the remanufacturing system, the question of acquiring cores is an important issue for the remanufacturer in order to be able to satisfy the demand for remanufactured products. “*The challenge within the industry is not just how to manage irregular reverse flows, but how to obtain them in the first place*” (Seitz and Peattie, 2004). To illustrate the importance of a close relationship, Seitz et al. gives an insight from a vehicle manufacturer:

For vehicle manufacturers, a crucial issue is to maintain a relationship with customers so that when an engine fails, the customer returns to the retail network for a replacement. If the customer goes elsewhere, then the loop will not be closed and the manufacturer will not get access to the cores they need. Unfortunately, loyalty to OEM service schemes decreases noticeably over time.

Here, the management of different types of relationships with the customer and suppliers is an important factor for the performance of the remanufacturing system. As Seitz and Peattie (2004) put it, “*reverse logistics and remanufacturing are a customer relationship management challenge*”. A main conclusion from their study is that remanufacturing is

typically discussed as a production and logistical challenge added on to a conventional system of consumption. To develop further, remanufacturing also needs to be considered in a customer perspective. For example, customers who demand remanufactured engines are typically car users who generate high mileage during short periods, such as those who drive taxis or vehicles for mail-order firms. These are customers who depend on their vehicles and are unlikely to accept delays in obtaining a replacement engine. These may also be longstanding and loyal customers.

1.1. Aim

The aim of this research is to identify what kind of relationships exist between remanufacturers and their customers/suppliers of cores, and how these relationships can be managed. Furthermore, in this paper we will explore how customer/supplier relationships perspective can support product take-back for remanufacturing with focus on the supply of cores. When considering the supply of cores to the remanufacturing process, the focus is on the relationships with the customers/suppliers of cores and how the supply of cores to the remanufacturer can be managed in the remanufacturers' perspective.

This research also aims at contributing to previous research by theory building. This aim is pursued through case study research at remanufacturing companies; this is further elaborated on in the next paragraphs called “previous research” and “research methodology”.

2. Previous research

Previous research has reported different systems and techniques for gathering cores for remanufacturing. A common observation is that off-lease and off-rent products are an important source of used products for remanufacturing. Thierry et al. (1995) have come to the conclusion that this type of return is more predictable than other types of returns due to the additional information that is available to the remanufacturing company. In the automotive industry, there is widespread use of “exchange cycles” where products are only sold if a core is given back (Seitz and Peattie, 2004). In this scenario you first have to act as a supplier of a core in order to become a customer of a remanufactured product. Other reported systems are voluntary systems where the supplier freely returns the used products/cores to a remanufacturer, or where the cores are bought from core brokers or end customers. The company Lexmark uses a “prebate” program giving a discount on a product if the customer

agrees to return the product after use; this program prohibits the customers from returning or selling their used products to other companies. Guide et al. present a number of management propositions on what to focus on when trying to balance the supply and demand for remanufacturing. Regarding core acquisition, one of the most important issues is to focus on identifying different sources of cores and rating them according to their characteristics. Forecasting core availability is critical in order to balance supply and demand. This reduces the need to purge the system of excess cores and reduces stock-outs of unavailable units. Managers should also try to synchronise return rates with demand rates, since doing so will lower the overall uncertainties in the system and lead to lower overall operating costs (Guide and Jayaraman, 2000).

According to Geyer and Jackson (2004), there are three crucial limitations that a remanufacturing firm needs to overcome: limited access of cores leaving the use phase, limited feasibility of product remanufacturing, and limited market demand for the secondary output from remanufacturing. Furthermore, a challenge that remanufacturers need to tackle is the fact that market demands for remanufactured products and the disposal of used products does not always overlap. This is often referred to as, the problem of balancing supply of cores suitable for remanufacturing and the demand for remanufactured products. These issues have been further studied by Umeda et al. (2005) (see Fig. 1).

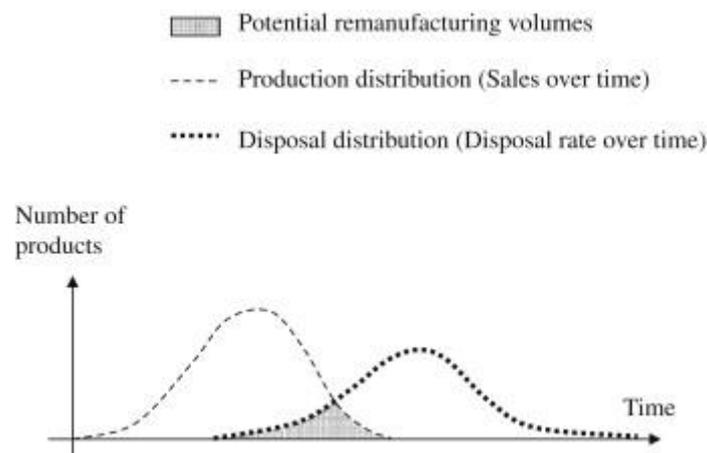


Fig. 1. An example of production and disposal distribution for same type of product (Umeda et al., 2005).

The reasons for returning used products are many. In theory, there are four basic types of returns: (1) *End-of-Life Returns*. These are returns that are taken back from the market to

avoid environmental or commercial damage. These used products are often returned as a result of take-back laws. (2) *End-of-Use Returns*. These are used products or components that have been returned after customer use. These used products are normally traded on an aftermarket or being remanufactured. (3) *Commercial Returns*. These returns are linked to the sales process. Other reasons for the returns include problems with products under warranty, damage during transport or product recalls. (4) *Re-Usable Components*. These returns are related to *consumption, use* or *distribution* of the main product. The common characteristic is that they are not part of the product itself, but contain and/or carry the actual product; an example for this kind of return is remanufactured toner cartridges (Krikke et al., 2004).

The issue of forecasting for used product returns has proven to be a difficult challenge for the remanufacturing industry. The return of mainly mechanical products is dependent on factors such as age and use of the product, whereas electrical products tend to have a more random pattern of failure. van Nunen and Zuidwijk (2004) report that different IT-based systems are used for keeping control over the products during use; two examples of these technologies are remote monitoring devices that communicate usage data and Radio Frequency Identification tracking systems used for keeping track of the installed base. Rogers and Tibben-Lembke (1999) characterise good gate keeping as “*the first critical factor in making the entire reverse flow manageable and profitable*”.

Another important characteristic in the closed-loop supply chain is the need for a well-functioning reversed logistic network (Guide, 2000). For example, reversed logistic networks for product recovery have been modelled by (Kara et al., 2007), with the aim to calculate the total collecting costs in a predictable manner. Kim et al. (2006) also present a closed-loop supply chain model for remanufacturing to minimise the total cost of remanufacturing. To estimate the effects of return complexity for capacity in the remanufacturing operations, Vlachos et al. (2006) present a dynamic model for capacity planning.

Furthermore, the reverse supply chain and remanufacturing processes are dependant on what type of relationship the remanufacturer has with the original equipment manufacturer (OEM) (Jacobsson, 2000). Remanufacturers are often categorised into three categories: original equipment remanufacturers, contracted remanufacturers and independent remanufacturers (IRs) (Jacobsson, 2000; Lund, 1983). OEMs are in fact manufacturers that perform their own remanufacturing as a part of their company group, whereas CRs have a contract with OEMs to perform remanufacturing for them. In the last category, remanufacturers work

independently from the manufacturers, and often as competitors in the same market. The type of remanufacturing category has a major impact on the supply of spare parts and cores (Jacobsson, 2000).

The relationship perspective has the starting point that the important issue is the mutual exchange of value that occurs during an existing relationship between different parties. In a relationship perspective it is not the individual transactions that are considered the most important. Instead the important thing is the relations that are considered to aid and support the transactions (Grönroos, 1997). These relationship and transactional perspectives are not mutually exclusive and there is no need for a conflict between them. However, one approach may be more suitable in some situations than in others. Transactional marketing can be considered most appropriate when marketing relatively low-value consumer products, when switching costs are low, when the product is a commodity, when customer involvement in production is low and when the customer prefer single transactions to relationships. When the reverse of all the above is true, as in typical industrial and service markets, then relationship marketing can be more appropriate (Egan, 2001).

In a relationship, many different characteristics or dimensions influence how successful a relationship can be. Studies have shown that there are up to as many as 45 characteristics that influences the overall relationship. Some of the most important characteristics for a successful relationship are cooperation, commitment, trust, power, consistency, adoption and attraction (Gummesson, 1994).

3. Methodology

The purpose of the design of a research methodology is to support the purpose and the research questions of a study (Yin, 1994). The research made for this study is based on empirical data gathered linked to several case studies of different remanufacturing companies as well as previously documented research in the area of remanufacturing. The research has its foundation in empirical data and links are made to the existing theoretical base. Hence, it follows an inductive reasoning. Inductive reasoning is based on a transition from specific observations to broader generalisations and ultimately theories. This is also called a bottom-up approach. In inductive reasoning, one begins with specific observations and measures, begin to detect patterns and regularities, formulate some tentative hypotheses that one can

explore, and finally end up developing some general conclusions or theories (Hartman, 1998).

3.1. Case study methodology

Case studies are particularly feasible in situations where the issues that are under investigation cannot be easily separated from their context or environment (Yin, 1994). By using case studies, one can gain a complex and holistic view of a specific issue or problem. A case study can be described as “problem-focused, small scale and entrepreneurial” (Merriam, 1994). Some specific abilities can be linked to case studies. According to Merriam (1994), case studies can give guidance to the reader in to what can be done, and what should not be done, in a similar situation; regard specific situations and still conclude to a general problem; illustrate the complexity of a situation, e.g. the fact that not a single but a multiple of variables affect a given situation.

As this research aims at building theory from case studies, some previous methodology research has been studied. Eisenhardt provides a suitable process of building theory from case studies according to Fig. 2. The research for this paper has followed the process shown in Fig. 2 in general (Eisenhardt, 1989). No hypotheses have been stated for this study since this was not suitable for the task.



Fig. 2. The process of building theory from case study research (Eisenhardt, 1989).

According to Eisenhardt theory building from case study research is particularly appropriate when little is known about a phenomenon because theory building from case studies does not rely on previous literature or prior empirical evidence. In the remanufacturing literature not much research about the importance of customer/supplier relationships has been found. Also, according to Voss et al. (2002) the theory building purposes with its unspoken research questions is facilitated by multi-site case studies. Hence, the case study methodology was chosen since it is suitable for qualitative research and theory building.

3.2. Empirical investigations

The empirical data for this study are linked to a research project “REKO” (2006) employing an explanatory multiple-case study concerning multiple types of products. The main source of data collection was semi-structured interviews with remanufacturing companies. The questions formulated for this type of study are normally open and give the respondents a chance to go in to detail regarding the answers, i.e. the questions were prepared without specific sequence or answering options (Jacobsen, 1993). Prior to the interviews, a theoretical literature review was performed; this review was the basis for the formulation of the interview questions (Östlin, 2006). The formulation of the interview questions were reviewed and given feedback on by the research group linked to the REKO project. After the formulation of the questions a pilot study was made to verify the validity of the questions. The main source of data for the case studies was interviews, these interviews were recording and the length of the interviews varied from 1 to 4 h depending on how much information that the interviewees had to contribute with. Typically, the interviewees were facility managers, production managers, controllers and technicians. Other sources of data were direct observations made under the study visits to the companies, as well as documentation in the form of photographs, brochures and information from the Internet (independent as well as issued from the case companies). These sources were mainly used for data triangulation.

The case company selection was made from companies that were found in the study of the remanufacturing industry in Sweden (Sundin et al., 2005). In this study, a multitude of potential companies was found. The choice of case companies was made based on variables concerning their annual remanufacturing volumes, as well as product complexity and remanufacturing process.

According to Eisenhardt (1989) there is no ideal number of cases, though a number between 6 and 10 is good for theory building. Empirical data were gathered primarily from different Swedish remanufacturing companies. The companies selected for the case studies were

Case company	Remanufactured products	Company size	Relation to OEM
BT industries	Forklift trucks	Large	OEM
Scandi-Toner	Toner cartridges	Small	Independent
Swepac International AB	Soil compactors	Medium	OEM
Tetra Pak	Filling machines	Large	OEM
Volvo parts	Engines	Large	OEM
UDB production	Automotive components	Medium	Contracted and independent

Other companies that can provide examples of the proposed relationships, on which no in-depth case studies were carried out.

Company	Remanufactured products	Company size	Relation to OEM
Greenman Toners	Toner cartridges	Small	Independent
Scania	Engines	Large	OEM
Turbo tech	Turbo chargers	Smal	Indipendent

It was found that these case companies were enough for this study since it provided us with good in-depth knowledge to fulfil the purpose of the study. Further cases would take to much time to investigate and this is according to Voss et al. (2002) an important skill in theory building from case studies to know when to stop.

4. Closed-loop supply chain relationships for remanufacturing

In the remanufacturing industry there are many different types of relationships with customers and core suppliers. Some relationships are very close, such as where the amount of trust, commitment and collaboration is high; in other relationships, the linkage is rather weak.

Even in the latter case, the relationship still exists and constitutes an important issue for the remanufacturers as well as the customers. In this study, seven different types of structural relationships have been identified. These relationships are

- *Ownership-based*: this type of relationship is common when the product is owned by the manufacturer and operated by the customer, as for example in a rental, lease or product-service offer. Here, the control of the installed base is high and often regulated by contracts.
- *Service-contract*: this type of relationship is based on a service contract between a manufacturer and a customer that includes remanufacturing.
- *Direct-order*: the customer returns the used product to the remanufacturer, the product is remanufactured and the customer gets the same product back (if it is possible to perform a remanufacturing operation).
- *Deposit-based*: this type of relationship is common in the automotive industry. When the customers buy a remanufactured product, they are obligated to return a similar used product, thus also acting as a supplier to the remanufacturer.
- *Credit-based*: when the customers return a used product they receive a specific number of credits for the returned product. These credits are then used as a discount when buying a remanufactured product.
- *Buy-back*: the remanufacturer simply buys the wanted used products from a supplier that can be the end user, a scrap yard or similar, or a core dealer.
- *Voluntary-based*: the supplier gives the used products to the remanufacturer. The supplier can also be a customer but do not have to be.

Concerning these different types of relationships, some disadvantages and advantages can be identified. As will be shown, these relationship structures are not used individually but are rather integrated (Table 1). For example, the deposit-based relationship will have to be complemented with another alternative, due to the inevitable fact that not all cores can be remanufactured.

Table 1: The use of supply chain relationships in relation to the companies studied for this research

	BT industries	Tetra Pak	Swepac	UBD production	Volvo parts	Scandi-Toner
Ownership-based	X					
Service contract		X	X			
Direct-order			X			
Deposit-based				X		
Credit-based					X	
Buy-back	X	X	X	X	X	X
Voluntary-based						X

The following paragraphs describe the seven identified customer take-back relationships for remanufacturing companies.

4.1. Ownership-based relationships

An ownership-based relationship is often related to a leasing, rental or a product-service offering as in the forklift truck (BT-industries) case. The basis for the ownership-based relationship is that some sort of ownership is still present for the seller, and that the product is given back to the seller after the end of use; it is also in this point that the remanufacturing operation is undertaken. Frequently, the seller is also responsible for maintaining the operation of the product. The seller can also be the manufacturer of the product as in the BT case. BT is also a remanufacturer of the used products. Because the offer is based on a contract, different levels of control and involvement can be used. In this type of relationship, the linkage between the customer and seller is strong. The time range of this type of relationship makes commitment an important factor. A respondent puts it like this: *“for a successful relationship the customer has to feel that our products and services are reliable”*.

In a product-service offering, the seller is directly responsible for the product in use by the customer. Naturally, the management of the relationship becomes increasingly important.

Issues like cooperation, trust, power and long-term commitment comes in to play. When a customer decides to enter in a relationship by signing the product-service offering contract, he becomes “locked in” by the seller and thus dependent on the same (Borenstein et al., 2000). “Customer lock” is when a customer becomes dependent on a seller for after-sales support. A practical example of this comes from TetraPak, which used to give away its filling machines and profit from the packaging material. In an ownership-based relationship, there is normally a high level of interaction between the customer and the seller, due to a high amount of after-sales service. For the relationship to be successful over a longer timeframe, the seller has to consider these issues.

The intensity can also vary dependent on the situation of the customer. In some cases, the product is rented to a customer for many years providing with regular servicing; other times, the products are rented for shorter periods, following for example seasonal demands. BT industries, which provides many of its forklift trucks through rental programs, explains it to its customers as follows (BT-Industries, 2004):

Think of the advantages. You avoid all the risks of ownership. You don't consume capital—not even a deposit is required. We take care of the equipment and make sure it's always reliable, and we work with you to manage your fluctuating need—we call it capacity management. Rental from BT means flexibility for the future and all of your costs are predictable.

(BT-Industries, 2004)

During the use phase, the seller is responsible for maintenance and repairs of the product; the maintenance technicians handle this commitment. By providing regular service and maintenance operations at the customer's location, a relationship is established through the service/maintenance personnel. Maintaining the relationship is an important factor of the BT policy of basing its service technicians at its major customers.

Another effect of a close relationship such as found in the BT case is that the service/maintenance personnel gain detailed information as to whether or not there is a need for a future remanufacturing operation. This information can make the return flow of products easier to control and provide information on the forklift truck status to the remanufacturing process. A high degree of control can for example be gained by high control

of the products that are in operation at the customer, also called the installed base. By using information gathered from the installed base, the supply chain can be effectively coordinated. This information can be gathered by, for example, service/maintenance personnel as in the BT case or by software solutions integrated in the product (used by for example Xerox in photocopiers).

The installed base of a rental/lease or functional provider is often called the “fleet”, and this term is also used at BT. The products in this fleet are either in operation by the customer (in use fleet) or waiting for a customer (buffer fleet) as shown in Fig. 3. High use of the installed base leads to a low size of the buffer fleet; vice versa, a low degree of use will indicate a larger buffer fleet. If the use of the installed base is too high (i.e. a small-sized buffer fleet), the company tends to have problems in supplying the demanded products and only the unneeded products are available. If the use of the installed base is too low, there are too many products in the buffer fleet. This leads to inventory holding costs such as value loss over time, obsolescence, cost of tied-up assets, etc. It is, therefore, important to have an optimal size for the buffer fleet, making correct sizing of the buffer fleet a crucial issue for management. From a remanufacturing point of view the size of the buffer fleet also has a major impact on remanufacturing capacity. In some situations the buffer fleet can work as a inventory providing a hedge against sudden demand peaks.

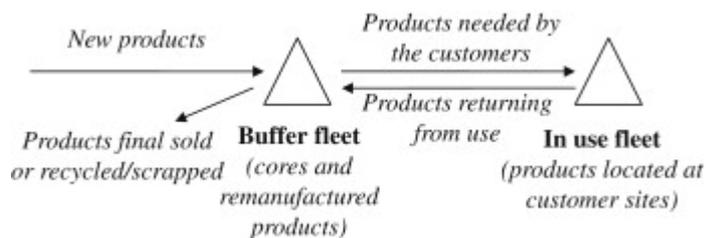


Fig. 3. The product flows between the customer and the remanufacturer in an ownership-based relationship.

As illustrated in Fig. 3, the size of the buffer fleet is dependent on the inputs (the return of used products (cores) and new products) and the output (the need for products and the number of products that are sold or recycled/scrapped). Information about incoming products can enable more accurate fleet management. To balance the size of the buffer has proven to be a difficult task due to the high number of variables that influence the need for the buffer. Some important variables are

Uncertainty in returns—a close relationship between the customer and the seller can reduce this insecurity. Still, there are situations where the customer wants to prolong the contract; this, however, will delay the return of the products. Furthermore, sometimes the used products are not returned immediately after the contract has ended. This also increases the delay of returning cores (product take-back).

Uncertain demand for products—accurately forecasting the needs for products is always a difficult task. This uncertainty can be reduced if the buffer fleets are coordinated in a wider perspective—for example on an international or national level as opposed to a regional level. By distributing products between regions and countries according to demand, the total buffer size required can be reduced. This is especially true for seasonal demands where a large number of specific products are needed for a limited period.

A high number of customised products that target a specific segment of customers—when dealing with leasing or product-service offerings, the physical product tend to remain at the customer for a long period. This first customer carries the major part of the finance for the product. For this reason, the sales department tends to be willing to customise the product, the result being that the product can become ill-suited for other applications. For example, a customer might want a specific reach height for their forklift truck. This makes the mast of the forklift truck taller than normal and unusable for other customers because it will not fit into their environment, limiting the forklift to a narrower range of customer. Here remanufacturing can provide a solution by changing the specifications of the forklift truck in the remanufacturing process, either to a standard or according to another customer's specification. Having this in mind, a standardisation and/or modularisation of product types would facilitate the downstream remanufacturing processes. Remanufacturing provides an opportunity to modify the specifications according to the customer's needs, given that the design of the product allows for modification.

Gaining control of the installed base provides more than just support for fleet management issues. By the information gathered from the customer provides detailed information about the lifecycle of the products in use by the customer. In this way the company can plan its sales activities according to the needs of the customer.

To operate product-service offers, the product needs to be combined with services. The development of a service system, as in the BT case, demands a high investment. Many of

these investments are needed because a producing company must transition from traditional manufacturing to also becoming a service provider, something which affects the entire structure of a company and increases requirements for administration. The transition from making products to services has been documented by e.g. Oliva and Kallenberg (2003). Also, when offering integrated, total or bundled solutions, the risk for maintaining the operations of the product is transferred from the customer to the seller. In this case, it is very important for the manufacturer to have a positive cost structure for the complete lifecycle of the product.

Furthermore, there are some challenges in product development that need to be tackled in a rigorous manner in order to achieve products that are adapted for integrated product and service offerings (see e.g. Sundin and Bras, 2005). If this is conducted successfully, the risks for product obsolescence will be reduced and the potential for a successful product-service operation will increase.

According to BT, remanufacturing volumes have been doubled during the last few years and they currently exceed the number of forklift trucks being newly produced in the ordinary manufacturing facility. This means that for companies like BT, the remanufacturing business has recently become a very important part of their overall business.

4.2. Service-contract relationships

This type of relationship has a high degree of similarity with the ownership-based relationship. The main difference is that the ownership goes over to the customer, thereby reducing the level of control over the products. This type of relationship is based on the formulation of a contract for aftermarket service. In the Swepac case, this contract contained clauses for repairs and maintenance as well as remanufacturing after a set period of time. The main difference between a service-contract relationship and an ownership-based relationship is the ownership of the product; a major similarity between the cases is that the offers are still regulated by a contract that has the major influence on the relationship. Given these similarities, the characteristics of the ownership-based relationships is still valid, although the lack of ownership and the characteristics of a service contract add some difficulties for the producers.

For Swepac, coordinating returns for remanufacturing has proven to be a difficult task, mainly because of the unwillingness to return products at a specified date. This problem is

rooted in the reduction in the customer's capacity when a product is being remanufactured. When a product is sent for remanufacturing, it is unusable by the customer; consequentially, this leads to unwillingness to return the product for remanufacturing at a specific time. As a result, the timing of the returns becomes unpredictable.

In this type of relationship, it is important to manage the remanufacturing activity. If the remanufacturer pushes the remanufacturing operation according to a contract, this can result in a negative response from the customer, dependent on if the customer needs the product at that time. This can result in a negative perception of the relationship in a customer perspective. One way to reduce this risk is to plan remanufacturing at a time when the utilisation of the product or the fleet of products is low. For example, Swepac performs its remanufacturing operations during the winter, when demand for compactors is less due to the ground frost. This is fundamentally the same problem as the companies that have a direct-order relationship, which is further described in the following section.

4.3. Direct-order relationships

In this situation, the customer gives an order for the remanufacture of a used product, as in the Turbo Tech case. Generally in the eyes of the customer, there is a problem in determining if there is a technical possibility to remanufacture the used product (core). Another uncertainty is what the price of the remanufacturing will be. The cost of the remanufacturing is dependent on the quality of the core and how much new material and labour will be needed in the process, and this is difficult to determine before the remanufacturing is undertaken. Regarding the pricing of the remanufacturing operation, there are different practises from company to company, and pricing can be variable to fixed. If fixed prices are used for remanufacturing, these risks of sending the used product to remanufacturing will be transferred to the remanufacturer.

In a case where the customer orders the remanufacturing, there is not normally a need to keep an inventory of cores; this is because the cores are supplied directly by the customer. Using a make-to-order system also reduces the need for a finished goods inventory. In some cases, remanufacturing to a direct order is the only alternative due to for example a lack of spare parts (normally due to the age, and consequentially the low volumes of the product).

In the situation of a direct-order, the cores from a customer have to be sent away for remanufacturing. Say, for example, that the core for remanufacturing is a component of a product; the result will be that the product will be non-usable for the time when the component is being remanufactured. This is not preferable for many situations; for example, a truck that needs to replace its turbo charger would have to stand still for a significant time while the turbo is being remanufactured. Most surely, the expenses for not using the truck are greater than the gains for the (potential) lower cost for remanufacturing. Still, this does not have to be the situation for someone who can wait for the remanufactured component while it is being remanufactured. Similar situations emerge when the whole product is remanufactured. For example, if a filling machine such as those described in the TetraPak case were to be sent to remanufacturing, the result could be that e.g. the complete process in a dairy would become inactive. In these types of cases other relationships can be more effective.

4.4. Deposit-based relationships

In this situation, the customer is obligated to return the core when buying a remanufactured product, thus becoming the supplier of cores. This system is common in the automotive industry, where the remanufacturer normally supplies a product to a sort of “middle man”, for example, an automotive part retailer as in the UBD example. The retailer pays a price and a deposit for the remanufactured product. When the retailers sell the product, they collect the used core from the customers; later, they return the core to the remanufacturer and their deposit is refunded, resulting in a one-for-one (1:1) take-back relationship, see Fig. 4.

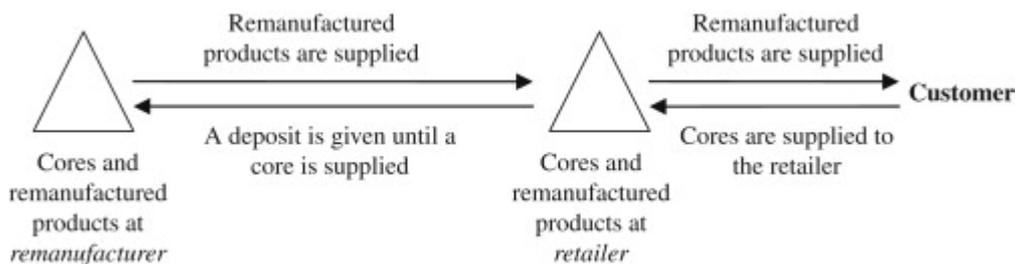


Fig. 4. Illustration of core/deposit flow in a deposit-based relationship.

This system creates a theoretical match between the supply of cores and the demand for remanufactured products due to the one-for-one link. An example of this is in the case of the brake calipers in a car (UBD case). In this case, the customer returns a number of brake

calipers that directly correspond to the remanufactured products needed by the same customer according to the 1:1 principle. This system also creates a win-win situation for both the customer and the remanufacturer: the customer gets a low-cost option by supplying, from their perspective, a low-value core, while the remanufacturer gets a supply of cores.

However, in practice UBD reports that the 1:1 link is not valid. In reality, some of the cores are still not being demanded due to many random actions, for example sales clerks failing to demand the take-back of the core. Another factor that reduces the theoretical 1:1 relationship is that a percentage of the cores that are returned cannot economically be remanufactured due to extensive damage that would require extensive reprocessing. The result of this mismatch is that the company must use alternative systems to gather the lacking cores. A common solution used by UBD is to buy-back cores from different kinds of scrap yards and core dealers.

In relation to the direct-order relationship, the deposit-based relationship enables the customer to get a remanufactured product back at the same time as the used product is given back. This has proven to be a strategically important ability, especially for business-to-business relations where maintaining functionality is a critical factor. Another important issue not to be neglected is that this type of relationship is common when dealing with warranty claims. To be able to provide a remanufactured product immediately once a product breaks down during warranty can help to create a positive relationship with a potentially unsatisfied customer.

Even though a perfect correlation can exist between supply and demand, there is always a lead-time for a single product to be remanufactured. For UBD, this means that the market introduction of a remanufactured product demands an investment in cores. These cores have to be gathered in another way. Due to the lack of cores in the market introduction, the system frequently has to invest in newly produced products.

Another issue and strategic question is the level of the deposit; if the price of the deposit is too low, the cores tend to disappear and a supply problem arises. A practical example can be taken from an auto repair shop where the repair staff throws away the core and charges the customer for the deposit, or the core is sold to someone who pays a higher price. Vice versa if a higher price is paid for the deposit the greater the chance that the core will be returned. At the same time, the retailer is forced to tie up capital in deposits. This type of problem can be solved with, for example, an extended credit note.

With a deposit-based system, no consideration is taken about the quality of the core that is supplied to the remanufacturer. The result may be that the perceived cost of remanufacturing, according to the customer, becomes too high if a high-quality core is supplied. Vice versa, the value of remanufacturing for a customer supplying a low-quality core becomes higher.

4.5. Credit-based relationships

This type of relationship is similar to the deposit-based relationship, but provides a higher level of sophistication (Volvo Parts case). Instead of a deposit fee, the customers receive credits for what they supply to the company. The number of credits the customers gain from the supplied cores is dependent on the state of the core. The credit they have acquired gives them a discount when ordering a new remanufactured product, see Fig. 5. This credit system, however, does not have the same 1:1 relationship as the deposit-based system. This enables the customers to return as many cores as they wish.

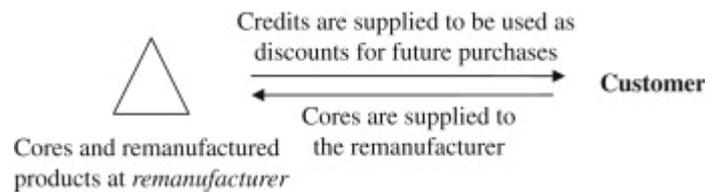


Fig. 5. Illustration of core/credit flow in a deposit-based relationship.

In the deposit-based system, no considerations are taken to the quality level of the returned core; it also does not motivate the customer to return more cores than the one-for-one principle. With a credit-based system, these considerations are taken into account. Credits are given according to two factors: (1) the quality level of the core, and if any of the specific components in the core are missing. (2) The amount of credits given is also variable between different types of products; highly demanded cores are given a higher credit; vice versa a low credit is given for unwanted cores. In this way, the remanufacturer gets a high variety of cores and can practice some level of control by the credit system, while the customer can return cores for credits. This type of system enables the remanufacturer to some extent control the balance between supply and demand. The credit system can also function as a method for assessing the incoming quality level of the cores according to the amount of credits given for returned cores.

This credit system can be proven ineffective as well. This type of system provides the customer with a high degree of flexibility to return cores, but the control and predictability will be more complex than with the deposit-based system. The system can also be taken advantage of by the customer, for example if the credits given are unbalanced. Respondents have reported cases when customers have given back 20 cores of low value (e.g. a water pump) and used the credits to order a high-value item (e.g. a remanufactured engine) that results in a major loss for the remanufacturer. In this situation, there is a lack of long-term commitment and cooperation that is needed for this system. One major disadvantage with this system is also that it creates a higher administrative cost for the remanufacturer. The customers will also be given an uncertainty in the number of credits they will receive for a specific core; this can result in a situation where price-sensitive customers hesitate to remanufacture, due to the uncertainty in price.

4.6. Buy-back relationships

Buy-back is as simple as it sounds; the remanufacturer simply pays out money for the cores. The sellers of a core, or multiples of cores, can be core brokers/dealers who specialise in the trading of cores, scrap yards or end customers. This type of relationship is present in most cases of remanufacturing, and it is used as a complement to some other type of relationship. It is common that the cores that are difficult to find are acquired in this way.

In many cases, buy-back is considered to be the last resolution if no other alternatives are present. For example, buying a product on a spot market is one way of buying cores; other more advanced systems are also used. One way is through core brokers, who have a close relation with their suppliers, often scrap yards. They are specialised in what they do and they have their own channels for acquiring cores. Maintaining a relationship with the suppliers is a strategically important issue. These core brokers are relatively frequent in the toner and automotive industries; the disadvantage can be the higher price paid (UBD and Greenman Toners).

Scrap yards can also be a good source for cores. Different levels of sophistication exist in scrap yards; in the UBD example, the company frequently visited a number of scrap yards to inspect their inventories and buy cores. Some scrap yards have sophisticated database systems, and online ordering is possible. In some situations, the OEMs have their own facilities for cannibalisation of components. The company Scania has a facility that buys

trucks that are in some way damaged, and cannibalise them for valuable components for reuse and remanufacturing. The main source of trucks in this case is those that have been damaged and are supplied by insurance companies.

When communicating with the customers in a buy-back relationship, UBD supplies its demands for cores to the customers, which in turn respond to the need of UBD. The suppliers of cores frequently also communicate concerning the types of cores available. In other situations, as in the Greenman Toner case, the cores are simply sent back to the remanufacturer, and the customer receives a refund according to a specified list.

Buy-back of products mainly results in customers getting money for their cores, although other systems do exist. Toffel (2004) reports a case where Lexmark uses a “prebate” program giving a discount on a product if the customer agrees to return the product after use. This program prohibits the customers to return or sell products to other companies. According to Lexmark, this program has boosted their return, although no reports about the efficiency of the program are given. The ability to gather “hard-to-get” cores is especially important when there are many IRs that want to retrieve cores for their business.

4.7. Voluntary-based relationships

This sort of system is common in the recycling of different types of material such as newspapers. It also exists in the closed-loop supply chain with remanufacturing (Scandi-Toner case). As for recycling, this system is based on the idea that the customer will voluntarily give back the core. This system can also be forced on the customer and the OEM. This is done for example through take-back laws stimulated by EU directives like the WEEE directive (EU, 2003) and the ELV directive (EU, 2000).

One example of this is the toner business that is regulated under the WEEE directive; as a result, toner cartridges cannot be treated as ordinary office supplies since they have been previously used. This creates a recycling problem for the customer. Scandi-Toner recognises the embedded value in the discarded product that can be realised through remanufacturing. A recycling service is provided to the customer free-of-charge, and results in the access to used toner cartridges. The relationship is established by providing a take-back system that is realised with a return box that is (when full) sent to the company free-of-charge. The boxes are sent to the company randomly and can contain multiple cartridges. According to Scandi-

Toner, the take-back system also motivates customers to remain customers, and provides a sales opportunity since a customer is more likely to purchase remanufactured cartridges when they are supplying the used ones through the take-back system.

The cores are supplied for free; the cost for the company is the transportation and material handling costs. According to Scandi-Toner, a key issue for profitability is to acquire the cores to a low cost. The environmental advantages of remanufacturing are strongly promoted as a motivational factor due to the lack of financial stimuli. This is done both to acquire cores and for use in motivating sales. Of course, the environmental issues count as a sales motivation in the other types of relationships as well, and not just in the Scandi-Toner case, but it is here where this issue is most actively marketed to the customer. A strong relationship with the customer is important; if possible, the integration with the customer should be as high as possible. An example of this is the free-of-charge return box used by Scandi-Toner.

The voluntary take-back relationships can generate a high supply of cores that in many situations have low demands for remanufacturing; this can lead to high levels of obsolete cores in inventory. A key issue is to keep this tendency at a minimum, continuously reviewing core inventory according to long-term forecasted needs. This type of relationship can also lack the ability to motivate the return of valuable cores that have a high demand for remanufacturing. The cores that are the most valuable do have a value and are subject for buy-back from competitors. A challenge here is to make the customer long-term committed to the company.

5. Discussion

Previous research has highlighted that there is some major difference between the “normal–forward” supply chains and the closed-loop supply chain with remanufacturing (Guide et al., 2003). In previous research the characteristic of the closed-loop supply chain are explained and the implications of these characteristics have been modelled. Although in a management perspective it is important to go one step further, not only to realise that it is a problem to be handled but also on how to reduce the source of the problem. By applying a relationship perspective to the area of remanufacturing and the closed-loop supply chain, important insights can be gained. The importance of managing relationships has also been proven a prosperous and important issue in the supply chain management literature. Christopher (2005) adapt the following definition of supply chain management:

The management of upstream and downstream relationships with supplier and customers to deliver superior customer value at less cost to the supply chain as a whole.

In a closed-loop supply chain the management of relationships becomes even more important as the supplier of cores and the customer often are the same person or company.

In this paper, seven different customer/supplier relationships have been identified in the closed-loop supply chain. Each company has different resources and abilities that limit them to some specific relationships. For example, the ownership-based and the service-based relationships are mainly linked to OEMs, and are less common among the IRs. As a result, none of these relationships are suited for every company. Another important issue is that these relationship structures are not used individually; in reality, some of these relationships are used simultaneously to compliment each other. One general observation from this study is that buy-back relationships are generally present in all companies that are involved in remanufacturing. Buy-back is normally not the major source of cores, and it is used only for the “hard-to-get” cores. The buy-back of cores also serves other strategic issues. For example, the buy-back of a product can both provide a sales opportunity as well as protect sales in the aftermarket (Sundin and Bras, 2005). The ability to adapt a specific type of relationship is dependent on multiple factors. Issues such as the type of product and the interest from the customer to have a relationship will influence the success of a specific type of relationship. A summary of these different findings is given in Table 2.

Table 2: A summary of the relationship characteristics in a remanufacturer perspective

Relationship	Core control	Relationship focus	Characteristics
Ownership	High, returns are often regulated by contracts	High, long-term relationships focus on integrating products and services	Used by OEM with a high degree of interactions with customers that focus on the function (e.g. reliability) of products
Service contract	Medium high, return probability are dependent on different contracts	High, long-term relationships focus on adding services to the products	Used by OEM with a high degree of interactions with customers that want to own the products
Direct-order	High, cores are supplied to an order	Low to medium according to importance of the product in respect to customer operations	Suitable in situations when: the product can be sent off for a longer period of time—no new parts are available—the price of remanufacturing is an important issue—the customers want the same product back as sent in
Deposit-based	Medium, a theoretical 1:1 relation exists	Low, transactional focus	Can provide a remanufactured product immediately once a product breaks down, e.g. during warranty
			No considerations about the quality of the core is needed
			Commonly used in the automotive industry
Credit-based	Medium, enables some control opportunity, no strict 1:1 relation	Medium to high, based on long-term cooperation	Considers and compensates for different quality levels of the core
Buyback	Medium, one can control what you want to buy or not	Low to high, ranges from buying cores at spot price to long time collaboration with e.g. insurance companies	Used manly as compliment to some other type of relationship
			Used especially for acquiring hard to get cores
Voluntary	Low, the company gets what the customer is willing to give	Low to high, focus on providing the customer with a positive environmental profile	Minimising the cost for acquiring cores

Regarding the different types of relationships, the ownership and the service-based relationships have the highest control over the installed base, and have a favourable position in gaining information about the installed base. The higher degree of control gained by the detailed information can decrease uncertainty in the quality level of the incoming product (core). This information, combined with detailed contracts about the duration of the contracts and the point of return, allows the remanufacturer to predict the timing and quantity of the returns and ease the need to balance returns with demand. In an earlier study, Thierry et al. (1995) come to the same conclusion when they write that “*companies that lease their products are generally in a more favourable position than companies that only sell products. Lease companies usually have more information on the quality and return of used products*”.

With the information about the status of the installed base gained from the customer, the seller can be one step ahead, realising the needs of the customer before the customer themselves. In a sense, a seller can control timing of different activities according to its ability to perform at its best. For example, sale advantages can be gained when the products that are close to their end-of-use are to be replaced. This information can then initiate a proactive sales activity. Another example is when an innovation pushes the product's usage out of its economic lifetime. According to Holmlund (1997), the actions in these sequences have great influence on the perception of the relationship. Without the information about the customers installed base, this advantage would not be possible. As a compliment, the information about the customer also gives an information advantage over the competitors.

In the ownership and service-contract types of relationships, there is an increased focus on delivering a function. With the increased focus on functions, the downside is that the perceived risks of the customer can increase. During the time that the product is remanufactured, the customer loses the functionality of the product, which can cause a negative sequence in the relationship. By minimising the loss of functionality, the perceived costs of the relationship can also be reduced. The company Swepac solves this challenge by performing remanufacturing when utilisation of its products is low. Other solutions can be to compensate the loss of function with another product; this is a strategy frequently used by, for example, auto repair shops.

In direct-order relationships, the risk of loss of function becomes especially apparent. From the perspective of the customer, this system generates a high risk, as well as lack of functionality when the product is away for remanufacturing. In addition, the way the pricing

of the remanufacturing service is undertaken is a source of risk. Pricing of a remanufacturing service can be variable or fixed, resulting in different levels of perceived risk in the eyes of the customer. These disadvantages make this type of relationship only suited for a limited range of situations, mainly when

- the product can be sent off for a longer period of time,
- when no other type of spare parts are available,
- when the price of remanufacturing is an important issue and
- when the customers want the same product back as they sent in (e.g. customised products with high value).

A deposit or credit-based system would be more appropriate in situations where it is critical for the customer to maintain functionality of a product. This is due to the importance of being able to provide a remanufactured product/component as soon as possible. The advantage with these relationships is that they can provide a replacement right away. One important aspect of this system is that it demands an initial investment in cores when a new product type is starting to be remanufactured. The main implications are that this system is preferable for rather standardised products with a high volume, e.g. toner cartridges.

Regarding deposit and credit-based relationships, the major difference is the level of sophistication. The credit-based system has an additional function of stimulating the customer to return specific cores. From a customer-relationships perspective, this system will be most fair. This system also stimulates cooperation between the parties. The accumulation of credits also stimulates a long-term commitment to the remanufacturer. Overall, the credit-based system relies on commitment, trust and the win-win situation, compared to the more transaction-based and deposit-based relationships. In this type of relationship, the gate-keeping function is very important. Gate keeping in this context means the screening of the cores that are coming back to the entry point of the reversed logistic network. The foremost important issue of the gate-keeping function is inspecting cores and giving the appropriate number of credits.

Voluntary-based relationships are based on the idea that the customers will voluntarily give back the core. This relationship system can also be forced on the customer and the OEM with take-back laws. To stimulate customers to give back their used products, relationship

management becomes important. Some negative effects of this system are that it can generate a high supply of cores that in many situations have a low demand for remanufacturing. It can also lack the ability to motivate the return of valuable cores that have a high demand for remanufacturing. The environmental advantages of remanufacturing are strongly promoted as a motivational factor due to the lack of financial stimuli.

5.1. Result validation

Building theory from case studies attempts to reconcile evidence across cases, types of data, and different investigators, and between cases and literature increase the likelihood of creating reframing into a new theoretical vision (Eisenhardt, 1989). The triangulation by using other data collection methods rather than only interviews and comparisons with other companies made the results of this study more valid.

A drawback of theory building from case studies is that the intensive use of empirical data can yield theory which is overly complex (Eisenhardt, 1989). Hence, the result can be theory which is very rich in detail, but lacks the simplicity of overall perspective. Having this in mind—the different closed-loop supply chain relationships presented in this paper should only be seen as important factors in the management of reverse supply chain management.

Strong theory-building research should result in new insights. Theory building which simply replicates past theory is, at best, a modest contribution (Eisenhardt, 1989). Furthermore, replication is appropriate in theory-testing research, but in theory-building research, the goal is new theory, as in this research study.

6. Conclusions

This research has been building theory based on case study research. By identifying the closed-loop supply chain relationships, a higher understanding can be gained about the structure of the remanufacturing industry and the characteristics of the relationships. The identified relationships are *ownership-based*, *service-contract*, *direct-order*, *deposit-based*, *credit-based*, *buy-back* and *voluntary-based* relationships. These individual relationships have different characteristics and are suitable in different situations as described in the previous section. The more general conclusions about how the relationships can be managed are

Firstly, one should understand that these relationship structures are not used individually; in reality, some of these relationships are used simultaneously to complement each other.

Secondly, a proposition is that the more important a product is for the customer's operations, the higher is the will to have a closer relationship as in an ownership or service-contract relationship. Also, the perceived risk of the remanufacturing operation has a strong influence on the willingness to become involved in a closer relationship. Issues like cooperation, trust and long-term commitment are important in these types of relationships. When managing these types of relationships, the focus should be on reducing risk and the perceived relationship costs.

Thirdly, a higher degree of control over the installed base can enable the OEM remanufacturers to control the timing of activities in the relationship (as in an ownership or service-contract relationship). The information can enable a seller to be one step ahead, realising the needs of the customer before the customer themselves. In a sense, a seller can control timing of different activities according to its ability to perform at its best.

Fourthly, remanufacturing can be a source of negative responses in the relationship. This is especially apparent when the remanufacturing operation results in a loss of functionality in the customer's value-adding process. One way of reducing the risk of a bad response is to plan remanufacturing at a time when the utilisation of the product or the fleet of products is low and thus reduce the perceived cost of the relationship.

Fifthly, one proposition is that remanufacturing becomes more effective when there is a clear win-win situation for both the customer and the remanufacturer. In the sense that the customer enables the low-cost option of remanufacturing by supplying, from their perspective, a low-value core, at the same time as the remanufacturer gets a supply of cores.

Sixthly, take-back systems can be taken advantage of by both customers and suppliers, for a long-term successful relationship there is a need to have mutual commitment and trust.

To conclude this paper, the success of a remanufacturing business is very dependent on the relationship between the remanufacturer and the customer, since the customer can both act as a supplier and a customer to the remanufacturing company. Since the retrieval of used products is crucial for the remanufacturer, the management of these supplier/customer

relations is very important. The companies studied in this paper all recognise that the management of the relationship with their suppliers/customers has contributed to their business success.

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