Strategic considerations in conceiving closed-loop product-service systems: a manufacturer's perspective





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°turn too

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Abstract

Growing resource consumption and waste generation of modern societies have given rise to governmental policies of extended producer responsibility. Together with increases in resource prices and price fluctuations, as well as mature markets for many products, this development drives manufacturers to innovate in their way of doing business. The concepts of product-service systems (PSS) and closed-loop supply chains (CLSC) show potential to address these business challenges. This explorative research examines, with a focus on strategic management, the characteristics and implications of PSS and CLSC from the point of view of a manufacturer of assembled products. Also, the complementarity of PSS and CLSC is assessed. The goal is to provide a starting point for thorough and in-depth research on 'closed-loop product-service systems'. An extensive overview of factors influencing PSS and CLSC implementation was constructed by combining qualitative information from 129 scientific articles and 15 semi-structured interviews with academics, field experts and practitioners. The strategic significance of these results was assessed using the concepts of strategic resources, strategic positioning and co-alignment of organization and environment. The concepts of CLSC and PSS were found to be complementary: a function-based business model like PSS facilitates resource recovery, and CLSC is a way of actualizing PSS' environmental benefits. Knowledge gaps were identified in the research fields of PSS and CLSC, which need to be addressed for more thorough investigation of closed-loop PSS. The strategic significance of the two concepts is found to depend strongly on contextual factors, such as characteristics of the product, distribution network, nature of the customer, and organizational aspects of the manufacturer. However, due to their sensitivity to context, close customer relation, and strategic fit between activities, the strategic position of the closed-loop PSS approach requires trade-offs with other positions and can be considered an imperfectly imitable set of resources.

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1. Introduction

1.1 Problem formulation

The issue of sustainability has been on the global agenda for some years. Important elements of the sustainability debate are the looming scarcity of certain materials (e.g. rare earth minerals, phosphate and oil) and the growing quantities of waste generated by society. (Hoornweg and Bhada-Tata, 2012)

Framing the rising quantities of waste and associated waste management costs as externalities of production, governments (primarily in the Europe and North America) have conceived the policy of extended producer responsibility (EPR). EPR aims to shift full life-cycle responsibility for a product, including waste management, from society to manufacturers. An implementation of the EPR principle is take-back legislation for specific product groups and a well-known example of take-back legislation is the Waste Electrical and Electronic Equipment (WEEE) Directive in the European Union. (EU, 2012)

Next to the issue of growing waste quantities, society is confronted with (the risk of) natural resource scarcity. (Krautkraemer, 2005) A glance at a leading scientific database shows that the research community has primarily considered natural resource scarcity from a macro-level perspective.¹ However, it is likely that individual businesses and eventually entire supply chains need to cope with this threat as well. Manufacturing firms are particularly prone to negative consequences of natural resource scarcity, natural resources being among their primary inputs for business activities. (Bell et al., 2012)

As a potential response and guiding framework to cope with the issue of natural resource scarcity on the firm level, Bell et al. (2012) suggest the use of the closed-loop supply chain management concept (CLSC). CLSC management is defined as the design, control and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time. (Guide and van Wassenhove, 2006) As it can be inferred from this definition, CLSC management is at the same time a way of forestalling natural resource scarcity and pressures by EPR legislation.

However, the voluntary basis of CLSC management means that the adequate management of end-of-life products and materials is not guaranteed: firms are not held accountable if they, for whatever reason, choose not to recover products and materials. Ensuring recovery through laws and regulation is one of the possible responses, but it entails costs for both society and manufacturers. Another possibility is using firms' intrinsic motivation and incentive to achieve competitive advantage as a driver for product recovery. This could be achieved through conceptually connecting product and material recovery with value creation.

Emphasis on value creation fits the trend observed by researchers of the "servitization" of industry. Servitization is the shift from traditional product sales to customer need fulfilment through combined offering of services and products.² (Vandermerwe and Rada, 1988) Offering a total need fulfilment-oriented solution creates more value for both the customer and the manufacturer (since economic value is moving

² In this research "customer needs" is interpreted in the common business sense: problems that customers intend to solve with the purchase of a good or service. (<u>http://www.businessdictionary.com/definition/customer-needs.html</u>) A discussion on the role of consumerism in achieving sustainability may yield different interpretations. However, this discussion is considered beyond the scope of this research.

¹ Titles of search results for "natural resource scarcity" in Scopus where judged for their perspective: the business/supply chain or government/national/societal level

from product sales "downstream" towards supporting services). (Wise and Baumgartner, 1999) Another driver for shifting sources of value is the commoditization of manufactured products; in many markets the potential for differentiation, and hence competitive advantage, in traditional manufacturing activities is decreasing. This drives manufacturers to shift towards providing services or even experiences. (Pine and Gilmore, 1998)

In recent years industry and the research community have increasingly observed and shaped business models that amalgamate services and products into need-focused solutions. A fairly prominent example of such a business model is the product-service system (PSS). PSS are defined as "an integrated offering of products and services that delivers value-in-use". (Baines et al., 2007)

By delivering value in terms of use (functionality), and not products, the incentive for manufacturers changes from making and selling more products to delivering more (or more efficient) functionality. In this way, PSS offer an opportunity to achieve sustainable growth for manufacturers in three respects: a solid basis for competition, addressing resource scarcity by retaining ownership over products, and responding to pressures applied by EPR legislation. These advantages can be illustrated using the concrete example of "Pay Per Lux", an innovative lighting concept by Philips. With Pay Per Lux the user pays for a contractually guaranteed amount and intensity of light on the working space, while Philips is responsible for the installation, energy costs, maintenance and eventual dismantling and tack-back of the lighting system. At the same time Philips is free in how they provide this required functionality. For example by opting for a control system that senses movement, the annual energy consumption of the whole system is reduced. Philips is incentivized to make use of energy-saving technologies since they will reduce the energy costs of the system (part of Philips' expenses) while Philips remains owner of the (costly) control system, which could be reused after the contract with the user has ended. The intense interaction with the customer during the duration of the contract and the strong focus on customer need fulfilment implies a basis for competitive advantage that is different from producing and selling lighting equipment at the lowest cost, and may be more difficult to imitate or substitute for competitors. Since Philips remains owner over the lighting system and could opt to reuse the system in another arrangement, costs are saved and resources conserved. And finally, the take-back of end-of-contract equipment is consistent with one of the primary goals of the WEEE directive: producer responsibility of end-of-use and end-of-life products. (Ellen MacArthur Foundation, 2012)

While the PSS business model incentivizes product recovery but offers no specific guidance on how recovery could or should be achieved, CLSC management does offer such 'practical' guidance but does not provide a business model that incorporates product- and value recovery into the basis for competitive advantage. In this sense, the two concepts are complementary. However, to the best of our knowledge, there has been no research investigating the strategic considerations and implications for manufacturers engaging in this 'conceptual duo'. From a firm's point of view, a strategic consideration forms the basis for concrete further development and action. Relating the potential environmental benefits (desired by governments and society) to possible strategic benefits for a firm can help accelerate the implementation of CLSC and PSS. On the other hand, if it turns out that implementing CLSC and PSS can erode competitiveness or is unlikely to realize the expected environmental benefits, this knowledge is also useful.

1.2 Research approach

The goal of this research is to initiate and stimulate research into the business strategic considerations for the 'conceptual duo' of PSS and CLSC. This research will hold the perspective of a manufacturer of relatively complex products³ using literature and interviews (with practitioners, academics and field experts) as source of information, and concepts from the strategic management domain for analysis. A qualitative and exploratory approach was adopted to reflect the early stage of this avenue of research.

This research has been conducted in cooperation with Turntoo; a Dutch Amsterdam-based company pioneering the implementation of PSS together with manufacturing and service providing partners for products that can be recycled and/or disassembled. With its partners, Turntoo co-creates function-based PSS by providing knowledge and a network, as well as creating societal awareness and thereby developing markets for PSS. Turntoo, being a young start-up, is in the process of mapping the issues that come into play when designing closed-loop supply chains for PSS. By making use of the Turntoo network we aim to identify and categorizing important factors in this underexplored yet promising field. The primary perspective of this research is the strategic management perspective, and the manufacturer is the focal actor in the supply chain. The manufacturer's perspective was selected because assembled products are assumed to have potential for relatively extensive value recovery and thus offer an interesting case for research, as opposed to bulk- and non-assembled products (although lessons may still be learned from these other product categories).

1.3 Research questions

Based on the preliminary assessment of the state of research on combined PSS and CLSC, the following research questions were formulated:

- What are strategic considerations, from a manufacturer's perspective, on developing value creating closed-loop supply chains for product-service systems?
 - What are characteristics of closed-loop supply chains and product-service systems?
 - How do characteristics of linear supply chains relate to the requirements of closed-loop supply chains for product-service systems?
 - What is the role of closed-loop supply chains and product-service systems in gaining sustained competitive advantage for the manufacturer?

³ Assembled products (e.g. computers) have the potential to be recovered in more ways and for this reason pose a more interesting subject than 'simple' products (e.g. t-shirts)

2. Conceptual framework

The core concepts of this research are product-service systems, closed-loop supply chain management and strategic management. In this section these concepts are described, although it should be noted that more details follow in section 4.1.1 and 4.1.2.

2.1 Product-service systems

Product-service systems (PSS) are business models that emphasize user need fulfillment through a combination of products and services. (Tukker, 2004) There are different types of PSS. A widely used categorization distinguishes between:

- **Product-oriented PSS**: the provider sells a product plus related services for during the use-phase of the product.
- Use-oriented PSS: the user rents or leases the product and gains unlimited access to it.
- **Result-oriented PSS**: the user pays either per unit of 'output' (e.g. driving hours in a car) of the product, or per unit of 'functional result' (e.g. unit of transportation) (Tukker, 2004).

In result-oriented PSS, only the functional results, not the means of providing them are *contractually* specified. This creates opportunity for delivering the same (or more) value as the traditional product sales offering, while using fewer (material) resources.⁴ In general PSS are regarded as an opportunity to reduce resource consumption and waste generation of modern societies. (Mont, 2002) (Tukker, 2013) However it is commonly assumed that only result-oriented PSS are attributed potential to reduce it with a factor 4 or 10.⁵ (EU Commission, 2008)(Mont, 2002)(Tukker and Tischner, 2006) However, lacking quantification impedes advancement of knowledge on PSS benefits. (Heiskanen and Jalas, 2003)

Besides a reduction in resource consumption, PSS are also generating interest as a possible means to achieve and safeguard competitiveness and profitability for manufacturing firms, especially in mature markets. There is more value to be captured "downstream" in the supply chain (with services that complement products) than with product manufacturing. By focusing on customer needs, manufacturers can capture that value. (Baines and Lightfoot, 2013)(Tukker, 2004)(Wise and Baumgartner, 1999)

Customers are said to benefit from PSS for example in the form of higher quality and more customized goods and guaranteed operability through included service and maintenance in the offering. (Mont, 2002) However, the propensity of customer to adopt 'ownerless-consumption' is not homogeneous but expected to vary depending on the type of market (business-to-business or business-to-consumer), and on social and economic factors such as location (urban or rural), age, and level of income (Heiskanen and Jalas, 2003) (Gottberg et al., 2010)(Tukker, 2004)

In table 1 the (expected) environmental and economic benefits are summarized. These are the benefits that are referred to in this report, unless stated otherwise. Many of these claimed environmental and economic benefits of PSS remain to be thoroughly tested. In particular, the sustainability benefits of PSS hinge on manufacturers 'closing the loop' and investing in eco-efficient products and technologies. (Vasantha et al., 2012)[. However, it has to make (long-term) business sense to close the supply chain

⁴ It is this type of PSS that Turntoo, the company supporting this research, is pushing and developing with its partners.

⁵ The concept of factor 4 and factor 10 reduction of impact is derived from (Schmidt-Bleek, 1997)

loop: firms rarely take such action purely out of environmental concern. The PSS research field offers virtually no guidance on how to close the loop. If significant environmental benefits are to be achieved, more attention needs to be paid to this aspect.

Table 1: Economic and environmental benefits of PSS

Economic benefits	Environmental benefits
Higher profit margins by moving "downstream"	Reduced resource consumption and waste
(Aurich et al., 2010)(EU Commission, 2008)(Wise	generation (Cook et al., 2006)(Gottberg et al.,
and Baumgartner, 1999)	2010)(Halme et al., 2006) (Tukker, 2004)
High customization and customer loyalty (Aurich et	Incentive for eco-design: Design for Disassembly
al., 2010)(Tukker, 2004)	(DfD), Design for Recycling (DfR) (Roy, 2000)
High potential for fast product innovation (Aurich	Incentive for 'closing the loop' (Halme et al.,
et al., 2010) (Tukker, 2004)	2006)(Mont, 2002) (Sundin et al., 2010)

Although PSS has many similarities to leasing, PSS provide more incentives for sustainable design: e.g. including costs of use and disposal/recovery costs in the price paid for the service. Despite the differences, in this research PSS and leasing are considered comparable. This simplification facilitates contrasting of the CLSC and PSS research fields, since in the CLSC field leasing is frequently mentioned as an arrangement facilitating CLSC implementation

2.2 Closed-loop supply chain management

Closed-loop supply chain (CLSC) management is the design, control and operation of a system to maximize value creation over the entire life cycle of a product. (Guide and van Wassenhove, 2006) It concerns the dynamic recovery of value from different types and volumes of returns over time. (Guide and van Wassenhove, 2006) Academic research around this practice developed out of operations research (OR), and initially focussed on the challenge of optimizing management of unpredictable patterns of product returns in e.g. processing facilities. (Guide and Van Wassenhove, 2009a) This research consolidated and expanded its focus, in general terms, to uncovering sources profitability, strategic considerations like competition, and finally aspects like customer behaviour towards and perception of remanufactured products. (Atasu et al., 2008a)

In this research, recovery is understood in the broad sense of value recovery. This includes acquisition of end-of-use or end-of-life products, reverse logistics, inspection, reprocessing and eventually remarketing. The research field of CLSC overlaps with the field of reverse logistics in its technical approach to product recovery. However, the CLSC research field tends to emphasize the business perspective, while in reverse logistics the focus is on operational aspects. With the exception of fine-grained and very specific topics in the reverse logistics field (e.g. inventory management), reverse logistics is included in this research.

Since the terminology in the CLSC field is quite diverse, it is therefore useful to explicitly clarify the terms used in this research. They are presented in table 2.

Table 2: Definition of terms regarding recovery and recovered products

Recovery	Recovery of value through acquisition, reverse logistics, inspection, reprocessing and remarketing of returns.				
Returns	Products available (at the user) for recovery that may be already owned by the manufacturer (in case of a contract) or may have to be acquired.				
Retrieved products	Returns that have been transported to the inspecting or reprocessing party.				
Reprocessed products	Returns that have undergone any kind of reprocessing and are ready to be remarketed.				
End-of-Use (EoU)	Products discarded by the user or available after ended PSS/lease contract. Their quality varies between worn/damaged and 'as good as new'.				
End-of-Life (EoL)	Products at the end of their physical life and unusable for their intended function. Components may still be usable.				
Reverse logistics (RL)	Logistics of EoU or EoL returns from the customer to the inspecting or reprocessing party				
Forms of reprocessing (adopted from Thierry et al. (1995))					
Direct reuse	Directly remarketing a retrieved product, or doing so after cleaning it				
Repair	Restoring used products to "working order" at a quality level that is generally lower than "as-new".				
Refurbishing	Restoring used products to a specified quality, which is generally lower than "as-new" (may involve upgrading).				
Remanufacturing	Restoring used products to "as-new" condition.				
Cannibalization	Recovery of a few remaining usable parts from used products. The term "cannibalization" also describes a process in remarketing of reprocessed products. Therefore, in this research the term 'salvaging' is used to describe cannibalization of used products, following the example of the interviewee of Caterpillar.				
Material recycling	Reusing materials instead of product structures such as whole products or components. In this research, with recycling is meant producing recycled materials with the <i>same quality</i> as 'virgin' materials.				

2.3 Strategic management

The topics of CLSC and PSS are assessed for their impact on strategic decisions of manufacturers. In this section the research field of strategic management is defined and described. Three strategic management concepts are introduced that together form the assessment framework in this research: resource-based view, strategic positioning, and col-alignment of organization and environment. Firstly, important aspects of strategic management are identified through analyzing a consensual definition.

Definition and concepts

The field of strategic management has a convergent nature: many fields, including economics, marketing and sociology come together in strategic management. (Bowman et al., 2006)This (at least partly) explains the abundance of approaches within the field and a general lack of coherent identity found by strategic management researchers. (Hambrick, 2004)(Mintzberg et al., 2005)

Through collaboration with many strategic management scholars and analysis of strategic management texts, Nag et al. (2007) have arrived at a compiled and consensual definition of strategic management:

"The field of strategic management deals with the major intended and emergent initiatives taken by general managers on behalf of owners involving utilization of resources to enhance the performance of firms in their external environment." We find this definition consistent with the descriptions of strategic management in the book Exploring Strategy by Johnson et al (2007). Elements in the consensual definition that were considered important by strategic management scholars from a broad range of orientations (from economics to sociology) are presented in table 3.

Definitional element	Associated terms
Performance	Advantage, growth, returns, dominance
Firm (as a unit of analysis in the field)	Firm, business, company
Environment	Industry, competition, market

Table 3: Terms associated with elements from consensual definition (Nag et al., 2007)

In a resource-constrained world, notions of firm performance may change in ways that are not yet imagined. (Bell et al., 2012) This research will stick to the current view on firm performance. Developing an adapted view on firm performance may be helpful in framing the research, but it is beyond the scope of this research. Where possible, apparent limitations of the current view on firm performance will be pointed out.

Retrieving products from customers and delivering functionality as a service instead of selling products are likely to fundamentally change the relationship between the firm and the environment. The "downstream" component of the supply chain (e.g. customer and distribution channels) becomes a source of raw materials for the firm. Therefore the strategic relationship between organization and environment is given special attention in this research.

Co-alignment of organization and environment

In a conceptual paper, Bourgeois (1980) poses that strategic decisions are at the heart of "co-alignment of organizational resources with environmental conditions" and that the goal of co-alignment is to guide organizational activities. This statement can be considered equivalent with the core of the definition of Nag et al. (2007): using resources to enhance a firm's performance in its external environment. Bougeois' statement adds that enhanced performance is achieved through co-alignment.

Bourgeois goes on that strategy can be divided in two major classes, on the basis of their relation to the environment. Corporate strategy selects (from the general environment) the task environment(s) in which to compete, while business strategy is the company's competitive approach in the task environment(s). The elements of the task environment and business strategy, according to Bourgeois, are presented in table 4. The focus of this research is the co-alignment of organization and *task environment* through business strategy, thus not on corporate strategy. This focus corresponds to a situation where a manufacturer faces the choice of transitioning from a product sales model to *servitizing* its offering.

Task environment features			Elements of business strategy making			
Components	Customers	I.	Environmental scanning of risks			
	Suppliers	II.	Objective setting			
	Competitors	III.	Distinctive competence selection			
	Regulators	IV.	Resource allocation			
Attributes	Complexity	V.	Monitoring and control			
	Volatility	_				

 Table 4: Features of the task environment and elements of business strategy marking according to Bourgeois (1980)

Resource-based view of the firm

A broadly recognized theory of the firm that emphasizes the development of internal resources is the resource-based view (RBV) of the firm proposed by Barney (1991). RBV poses that firms can achieve sustained competitive advantage by the utilization and development of key strategic resources. Sustained competitive advantage is defined as value created through a strategy that is not currently implemented, or attempted, by an incumbent or potential competitor. It should be noted that changing environmental conditions could still make sustained competitive advantage redundant. Resources (assets, capabilities, processes, information etc.) are considered strategic resources when they are "VRIN": Valuable, Rare, Inimitable, Non-substitutable. The respective meanings of these criteria are described in table 5.

Criteria	Description
Valuable	The resource enables firms to conceive or implement strategies that improve its efficiency and effectiveness
Rare	The resource is currently not possessed by many other firms^6
Imperfectly imitable	The resource cannot be straightforwardly copied because it arose from a unique historical condition, causal ambiguity or social complexity
Non-substitutable	<i>Currently</i> no strategically equivalent resources exist that are common and/or easily imitable ⁷

Table 5: Descrip	ntion of the V	VRIN criteria	according to	Barney (1991)
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Porter's strategic positioning, trade-off and fit

RBV attempts to *identify* sources of sustained competitive advantage using the concept of strategic resources. In "What is strategy?", Porter details a clear vision on decision guidelines that attempt to *produce* advantage. (Porter, 2000). Porters' vision exists among various schools of thought and this paper was selected for its comprehensiveness and complementarity with the other two concepts.

Porter (2000) discusses the principles he believes to make up strategy: positioning, trade-offs and fit. Given Porter's emphasis on distinctive position and features of the firm, it can be reasonably assumed that his propositions apply to business strategy.

Positioning aims at finding a niche that allows the firm to deliver a unique value (mix) to a customer (segment) by doing different activities than rivals or performing the same activities in different ways. The different bases for positioning are described in table 6.

⁶ As long as there are not enough competitors in a market to induce perfect competition dynamics (in which case any profit margin would be 'attacked' by a competitor who offers the same value at a lower price), a particular valuable resource may generate competitive advantage for a firm and thus be considered rare.

⁷ One important limitation of RBV is its exclusive applicability to static situations and not to dynamic situations. (Priem and Butler, 2001) In relation to non-substitutability, this means that *currently* non-substitutable resources could be substitutable in the future, e.g. because of new technologies.

Basis for positioning	Description
Variety	The firm produces a set range of products, and
	aims to optimize and excel at production and
	distribution processes
Needs	The firm builds activities around serving the needs
	of a differentiated customer segment
Access	The firm serves customers on the basis of their
	ability to access its product (for example: serving
	rural, not urban customers)

Table 6: Description of the different bases for positioning according to Porter (2000)

The second principle that contributes to sustained competitive advantage is the requirement of a strategic position for trade-off with other positions. Only then does it prevent imitation by rivals and only then it is sustainable.

Finally, strategic fit is the consistency and mutual reinforcement of a firm's activities, which, as Porter stresses, is distinct from operational effectiveness (pursuing excellence in an individual activity). He notes that the desire of many firms to optimize activities individually, without paying due attention to the synergy between them, has resulted in firms focusing on "core competences" and outsourcing other activities to more efficient third parties. As a result, the outsourced activities become more generic, since it may even happen that competitors outsource to the same third party. Porter argues that fit is more central to competinces. Since competitive advantage than one might think based on the common focus on core competences. Since competitive advantage arises from the totality of a firm's activities, ensuring strategic fit between all activities reinforces protection against imitation. Interestingly, Porter notes "the growth imperative is hazardous to strategy", because it provokes actions that are inconsistent with the selected strategy and thereby erode its effectiveness. (Porter, 2000)

Porter's three elements of business strategy provide a useful interpretation of the selected focus of the research: the outcome and formulation of business strategy.

The results of the analysis of interview and literature will be assessed for VRIN resources, clues regarding strategic positioning, trade-off and fit, and contribution to coalignment of organization and environment. The criteria that will guide this assessment are listed in tables 4 and 5, and the three principles of Porter. Together, these concepts will indicate strategic considerations of PSS and CLSC.

3. Research method

A comprehensive view on the factors that impact companies' choices regarding both CLSC and PSS is currently lacking. (Atasu et al., 2008a)(Mont and Tukker, 2006) To initiate the formation of such an understanding, this qualitative research adopted an exploratory approach. Information is drawn from both literature and stakeholder interviews.

3.1 Literature review

To explore much-discussed issues and themes in the PSS and CLSC research communities, as well as identifying their knowledge gaps, were the purposes of the literature review.

The search terms, as well as the limitations of search results and the number of papers examined are detailed in Appendix I. Basic search terms were used (e.g. "product-service system" and "closed-loop supply chain") to allow for representation of prominent themes in the search results and thus maintain the research' explorative character. However, searches were repeated (with the exception of "reverse logistics" due

to the operational orientation of this field) adding the search term "business strategy" to more clearly identify papers with this research' specific focus. Articles were selected out of the search results on basis of direct or indirect relevance to the research question. For example, articles on PSS ontology (see section 4.1.1) were not directly relevant to the research questions but their abundance was striking and they were therefore included in the research. In these considerations, the exploratory character of the research was kept in mind. In total, 129 articles were selected from the search results. It should be noted that not all of these articles were used in the analysis, for example because the topic turned out to be too specific. Also, some articles used in the analysis were not in the original search: these were sources for articles in the search and we opted for referencing the original source.

The assessment framework for strategic significance of CLSC and PSS was developed progressively. The search for a broadly accepted definition of strategy produced the paper of Nag et al. (2007). Firms' relationships to the environment are central to their definition. Bourgeois (1980) was found to provide a useful conceptual view on the co-alignment of organization and environment through strategy. We identified the relevance of the resource-based view for the strategic management field in the textbooks of Johnson et al. (2007) and de Wit & Meyer (2003). The original paper by Barney (1991) was used as the basis for the criteria regarding RBV in this research. A critique on the theory (by Priem and Butler (2001)), along with a response to that critique, was also used to put the theory into context. Finally, "What is strategy?" by Porter (2000) was used because of the clear and comprehensive view on decision guidelines that *produce* competitive advantage.

3.2 Interviews

Semi-structured interviews were conducted with academics, consultants, manufacturing companies and providers of services (reverse logistics and remanufacturing). The interviewees were approached/selected on the basis of the relevance of their personal work or their organization to the research topic. Some of the interviewees are in the network of Turntoo, which facilitated access and planning. Other interviewees were found by Internet search, recommendation, scientific literature and in the network of the researchers. The diversity of expertise and background of the interviewees represents the explorative character of the research. Academic research, (re)manufacturing, logistics, business networks and consultancy are all facets of CLSC and PSS that are represented in the expertise of the interviewees.

Different approaches were used for interviews with academics and consultants than with practitioners. The topic lists of both approaches are included in Appendix II In interviews with academics and experts, intentionally ambiguous terms (e.g. "characteristics") were used to provoke new perspectives and insights. In interviews with practitioners, examples of interpretations of these ambiguous terms were provided along with the question (e.g. "characteristics" might mean customers, activities, drivers etc.). The research question addressing differences between closed-loop and linear chains was not directly addressed during the interviews. Instead, it was indirectly addressed through topics about specificity of 'closed-loop competences' and potential for differentiation from competition through a closed-loop approach'.

PSS and CLSC were covered in the same interview. Overlap between the concepts was assumed beforehand and observed during the interviews. Because of this overlap, the two concepts were not segregated during the interviews and statements can apply to both PSS and CLSC. In the analysis of interviews statements were categorized as being relevant to PSS and CLSC, not to both at once. However, by coding the 'multi-relevant' statements twice (for both PSS and CLSC) the overlap was accounted for.

Audio recordings were made of the interview if interviewee agreed to this, and all interviews except the one with Caterpillar⁸ were carried out in Dutch. Otherwise detailed notes were taken. For analysis audio recordings were transcribed and notes digitized.

In this report, information from interviews is referenced using the name of the organization. The reader is referred to Appendix III for details on the organizations and interviewees' function in their organization.

3.3 Analysis

Content of selected papers was studied, summarized and grouped in more general categories. Bottom up coding was performed on the contents of papers and interview transcripts (separately) to find themes and to group statements. As a starting point for this process, elements from the research questions were used (e.g. CLSC, PSS and strategic management). This process helped to identify links between concepts discussed in different articles. For example, balancing of new and reprocessed product sales in CLSC (a product acquisition issue) could be related to market dynamics and articles discussing incentives for retailers to collect used products. The process of categorization was iterative: categories were reevaluated as new content was added.

Coded information from interviews and categorized information from literature was compared and contrasted to find where the sources confirm, contradict and complement each other.

After comparing and contrasting, the categorized information was assessed for strategic significance using the criteria described in section 2.3. The resultant strategic considerations for manufacturers (when considering implementing closed-loop product-service systems) are preliminary and the product of a broad exploratory study with (limited) initial structure. They should be no means be considered exhaustive and are intended to provide a broad perspective and stimulate further research.

Finally, complementarity of the PSS and CLSC research fields was examined. Issues/shortcomings raised in the PSS and CLSC research fields are compared to the 'strengths' of the other field's approach, and possible synergies are pointed out.

4. Results

In this section, first the analysis of literature and interview data will be treated. Then the relation between linear chains and requirements for PSS and CLSC is investigated. Finally, strategic considerations for PSS and CLSC are assessed, followed by a suggestion for the complementarity of the concepts of PSS and CLSC.

4.1 Analysis of literature and interview data

The information obtained from interviews and literature was analyzed by comparing and contrasting statements and concepts found in both sources. The information regarding PSS and CLSC was analyzed separately. This section relates to the first research sub-question: What are characteristics of closed-loop supply chains and product-service systems?

4.1.1 Product service systems

After generating an overview of the information present in interviews and literature, using the method described in section 3.3, a set of five core themes was identified: PSS ontology, macro-context, (value creation) network, internal organization

⁸ Caterpillar Inc. is a multinational manufacturer and seller of machinery and engines that was interviewed for this research

and market and competition. The contents of each theme are discussed in turn, followed by a summary.

PSS ontology

Although development of PSS theory and PSS design are not central to this research, it was included because of its strong representation in the literature.

How PSS definition, classification and design are treated in literature shows us something about the theoretical state of the PSS field. This theoretical state could have consequences for the implementation of PSS by practitioners. For example, practitioners may overlook possibilities for transitioning into PSS when provided with simplistic classifications. Simplistic classifications are the consequence of inadequate regard to e.g. bases for distinction between types of PSS. Also, whether sustainability is essential or just incidental to the PSS concept can be inferred from how it is defined in literature. And a skew in the theoretical backgrounds of PSS researchers towards eco-design may leave important issues in e.g. marketing or (closed-loop) supply chain management underexposed.

A variety of PSS definitions and classifications is presented in table 7. Although some definitions of PSS include sustainability, alternative terms to PSS, such as ecoefficient services, are conceived to give sustainability a prominent position. Common definitional elements are functionality as a premise for business development (Tukker and Tischner, 2006) and the combination of product(s) and service(s) into an arrangement that aims to deliver this functionality or need fulfillment (Aurich et al., 2010)(Baines et al., 2007) (Tukker and Tischner, 2006) According to Vasantha et al. (2012) the emphasis in a definition depends on the perspective taken by the definer and can be a traditional product-marketing, a service-marketing or a product-management perspective.

Van Ostaeyen et al. (2013) pose that insufficient attention is paid to the bases of distinction underlying these systems. For example, the distinguishing features of the trichotomous classification system of Baines et al. (2007) and Mont (2004) are *allocation of property rights* and the *provider's role in the value production*. Van Ostaeyen et al. (2013) show that with thorough investigation into the nature of concepts like 'function' and 'result', a much more nuanced classification is possible with 16 forms. Such nuance can reveal new possibilities to practitioners for implementing PSS and in this way facilitate advancement of PSS.

PSS definitions	PSS classification systems
"Functional products are [] hardware combined with service support systems" (Alonso-Rosgado et al., 2004)	Base-, intermediate- and advanced services. (Progressively more performance oriented) (Baines and Lightfoot, 2013)
"A marketable set of products and services capable of jointly fulfilling a user's need. The product/service ratio in this set can vary, either in terms of function fulfillment or economic value" (Goedkoop and van Halen, 1999)	Tukker (2004) proposes a sophistication of the common trichotomous classification using eight subcategories.
"Tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs" (Tischner et al., 2002)	Using performance orientation of the dominant revenue scheme and the level of integration as dimensions, 16 categories are proposed by Van Ostaeyen et al (2013)
"An innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client	Result services, shared-utilization services, product- life extension services, demand side management (Roy, 2000)

Table 7: Definitions and classification systems found in literature

demands." (Manzini & Vezzoli, 2003)	
"An eco-efficient service is one which reduces the	Product-based services, electronic substitution
environmental impact of customer activities per	services, and information-based services.
unit of output. This can be done directly (by	(Bartolomeo et al., 2003)
replacing an alternative product-service mix) or	Heiskapen & Jalas (2003) Manzini & Vezzoli
indirectly (by influencing customer activities to	(2003)
become more eco-efficient)."	(2005)
(James et al., 2001)	

The skew in researchers' backgrounds in the PSS research field towards ecodesign, as noted by Mont and Tukker (2006), is reflected in the abundance of PSS design methods and tools. (Vasantha et al., 2012) Besides considerable dedication of the PSS research community to this aspect, there has also been some criticism. Mont and Tukker (2006) question whether a unified and elaborate design approach is a desirable goal. The sensitivity of PSS to specific circumstances may render general principles, and not elaborate design tools, the most useful form of guidance for PSS design. Other criticisms on research about PSS design are the lacking attention on business models, sustainability, roles and responsibilities of stakeholders, drivers for changing customer demands and accurate representation of qualitative factors. (Tukker, 2013)(Vasantha et al., 2012) Also, Cook et al. (2006) note that existing knowledge of PSS is insufficient to produce design methods that help engineers to create sustainable products.

In the interviews, it was noted that the PSS concept has implications for organizational science. (Radboud University) A network of actors offering functionality and subsequent recovery of products and materials is a situation that is underexplored from an organizational science perspective.

Macro-context

The macro-context of PSS that is relevant to the manufacturer is focused on governmental influence on PSS implementation and environmental aspects of PSS. Proven environmental benefits of PSS could result in goodwill from government and consumers towards manufacturers implementing this business model.

Currently, environmental and economic benefits of PSS are largely unproven, (Cook et al., 2006)(Heiskanen and Jalas, 2003) while there are indications of potential for e.g. reducing household waste. (Gottberg et al., 2010) The issue of scarce evidence receives relatively little attention in literature. The lack of evidence and also of understanding of firm behavior (regarding sustainability) in a PSS setting (Gottberg et al., 2010) (Tukker, 2013) makes formulation of effective policies that stimulate sustainable behavior in PSS complex. For example, in literature it was found that an incentive for increasing product durability and eco-innovation only occurs if the PSS provider is a manufacturer. At the same time, if a manufacturer's revenue comes increasingly from PSS, their investment in product innovation decreases. (Heiskanen and Jalas, 2003) This illustrates the complexity of these behaviors, and governments would benefit from deeper insight in how they can effectively influence firms' sustainability behavior in PSS.

Governmental systems (e.g. tax) are generally oriented on linear production & consumption. For example, the VAT-system depends on addition of value up to consumption, after which value is destroyed. (Connex, Polre Advisor, Radboud University, Spring Global Mail) This does not represent the model of PSS, and especially not closed-loop PSS. Uncertainty on how these structures will change poses a barrier for manufacturers considering implementation of PSS: pre-empting and complying with laws and regulations is a driver for PSS development. (Mont, 2002) The PSS community has not yet engaged in this issue, and this shows that many interesting facets of PSS' impact on the larger scale of society are underexplored. (Radboud University)

Value-creation network

The term value-creation network was selected over the more established concept of the supply chain to emphasize the non-linear nature of the network that jointly delivers the functionality of the PSS. In this theme the interactions and actors in a PSS delivering network are examined.

Implementing PSS necessitates the PSS-provider to align and coordinate PSS network actors in the production- and a service-provision network. (Schweitzer and Aurich, 2010) In PSS, the value creation network is required to change in a number of ways. Customer relations management needs to reflect the increased dependence on customers for supply in a closed-loop PSS (compared to linear chains) (Wageningen University²) and for feedback and design input (required for e.g. innovation). To align the PSS network actors, the network needs to be jointly conceived and developed. (Caterpillar, EPEA NL, Wageningen University^{1,2}) This joint development can be guided by a clear and shared "project vision": an attribute found to be important in aligning a PSS. (Ceschin, 2013) In case of a closed-loop PSS, the value creation network must be extended to include recyclers and possibly parties specialized in reverse logistics. (EPEA NL, Wageningen University²) The required extension of the value creation network often generates a more network production structure and thus higher transaction costs. (Tukker & Tischner 2006) This relates to the 'servitization paradox': servitized firms may show higher revenues, but lower profits. (Belvedere et al., 2013)(Brax, 2005)(Neely, 2008)

In line with the disregard of closed-loop design in PSS design methods, the closed-loop scenario is scarcely addressed in overall PSS literature. There are interesting (hitherto unanswered) questions regarding the business case for a closed-loop PSS: how to adequately create a business case that extends over multiple life cycles of the physical product? (Radboud University) And: how can the value of the information obtained through returned products or customer feedback be taken into account in the business case? Also, the sharing of benefits between PSS network actors is an interesting issue. (Tukker, 2013)

In the interviews the recovery process was addressed, due to the explicit attention paid to closed-loop supply chains. Conditions for feasibility of closing the loop in PSS is feasibility of higher order recovery (material value is low relative to product structure value) (Wageningen University¹) and costs of maintaining ownership in material recycling. (Wageningen University²).

Information sharing between PSS actors is at the same time crucial *and* problematic, since it is necessary for effective and responsive decision making throughout the chain but risks to reveal companies' sources of profit. Complexity of the chain, unwillingness, ignorance or lack of the appropriate information management capabilities can be reasons for ineffective or inefficient sharing of information. (DurabilIT, Wageningen University^{1,2}, Spring Global Mail) Designating a neutral, third party facilitator that anonymizes information before sharing it with other chain actors might solve these issues (EPEA NL, Erasmus University, PartTracker, Polre Advisory, Radboud University, Wageningen University¹)(Mont, 2002) The issue of hesitant sharing of information seems under addressed in literature, but was repeatedly raised in interviews.

Internal organization

Besides coordination of external actors in the PSS delivery network, the internal organization of the manufacturer needs to be adapted to function effectively in this network. Important aspects of internal organization in the context of PSS were found to be communication, culture, business models, and structures.

Strong communication between i.a. marketing, manufacturing and distribution departments is paramount to PSS' success, since it PSS relies on accurate assessment and fulfillment of customer needs. Accurate assessment starts with frontline staff competent in both social skills and in transmitting the information to the right places in the firm. (Baines and Lightfoot, 2013)(Tukker, 2013) Another important element in achieving this is "the harmonizer": (an) employee(s) dedicated to streamlining the communication and knowledge exchange between departments and updating them on each other's issues and ideas for improvement. (Caterpillar, Interface, MVO NL) Tukker (2013) finds that cross-functional management is a common feature in servicized firms. A cross-functional approach is also likely to address the influence of business model design and product/service design; this influence is observed but inadequately studied in literature. (Vasantha et al., 2012) Effective and full internal communication is impeded by fear of sharing information between departments: when developing a PSS this kind of social or cultural barrier need to receive explicit attention. (Wageningen University²)

Facilitating attributes of management culture in PSS are a long-term view (Wageningen University²), a multi-term strategic attitude and a flexible system approach to management (Ceschin, 2013): management should treat PSS as a trajectory that is open to changing circumstances, and not as a static goal. This management attitude must also be translated into firm structures such as key performance indicators (KPIs): only rewarding employees for minimized short-term risk and costs does not reflect a strategic commitment to a new concept like PSS. (MVO NL)(Cook et al., 2006) Escalation of risk must and can be prevented with effective 'warranty' management⁹. (Sundin et al., 2010) A specifically cultural issue for manufacturing firms is the increased retained responsibilities (compared to linear chains) that come together with retained ownership of products. (Radboud University, Wageningen University^{1,2})(Cook et al., 2006) Other important aspects of company culture that need to be addressed in PSS are awareness and priority of product quality, (Caterpillar, EPEA NL), service-culture (Kowalkowski, 2010)(Tukker, 2013), changing proposition from product to concept (service) (Tukker, 2013)(Kowalkowski, 2010)(EPEA NL), and perceived equivalence of new and recovered products (Erasmus University, Caterpillar, Wageningen University¹)(Ceschin, 2013).

Regarding the totality of topics found in the theme of internal organization, it stands out that in the interviews the theme of network coordination, employee-culture and internal communication were more prominent, while literature mainly examines internal structures like KPIs, warranty management, as well as service- and managementculture. It may be that the latter subjects are more readily definable and measurable. However, it seems that for a comprehensive understanding of the internal organization issues of PSS, both the 'softer' aspects of company culture as well as fundamental new questions in coordination of value creating-network cannot be left out.

Market & competition

With PSS, manufactures have the potential to grow in mature markets and to open new markets (Cook, 2004)(Cooper, 2011)(Firnkorn and Müller, 2012)(Minguez et al., 2012) Moving "downstream" by offering a 'total package' of product and service improves manufacturers' position in the value chain: a higher portion of the value resides downstream than in product manufacturing. (Baines and Lightfoot, 2013)(Tukker and Tischner, 2006)(Wise & Baumgartner, 1999) Also, the service component is hard to copy (inimitability is a trait associated with competitiveness in business management). (Cook et al., 2006) By offering bundled services, and where possible taking over tasks customers

⁹ Warranty technically applies to purchased products, but is meant here as managing contractual responsibilities of PSS provider *and* user

used to do themselves, new sources of revenue are created for manufacturing firms. (Interface)(Belvedere et al., 2013)(Minguez et al., 2012) PSS can increase customer loyalty to the PSS provider (Erasmus University)(Tukker, 2004): this asset is also described hard to copy. (Alonso-Rasgado et al., 2004)(Kowalkowski, 2010)(Mont, 2002)(Tukker, 2013) (Tukker and Tischner, 2006) Higher sensitivity to customer needs also improves potential for innovation. (Minguez et al., 2012)(Tukker, 2004)(Tukker, 2004)(Tukker, 2006) (Velamuri et al., 2011)

While the above mentioned factors seem to enhance competitive advantage, industries where excellence in manufacturing and design form the basis for differentiation and advantage are likely to disfavor PSS: investing in PSS diverts resources from the basis of competition in that industry, putting that manufacturer at a *disadvantage* (Tukker and Tischner, 2006) Interestingly, statistics indicate that servitized firms in general go bankrupt more frequently than traditional product selling companies, and smaller firms seem to be more successful in implementing PSS than larger firms. (Neely, 2008) Possibly, smaller firms can more effectively exploit and valorize feedback from products, customers and markets: an attribute mentioned in literature as important for the overall profitability of PSS. (Schweitzer and Aurich, 2010)

To customers, PSS brings flexibility in use and customization, and wider accessibility to high quality products. (Minguez et al., 2012)(Tukker and Tischner, 2006)(Mont, 2002)(Alonso-Rasgado et al., 2004) Also, reliability is one of the attractive features of PSS for customers. (Mont, 2002)(Tukker, 2013) PSS providers need to cost-efficiently maintain high reliability, while also ensuring shared responsibilities regarding product use to reduce risk. (Tukker, 2013) Also, costs incurred to accommodate flexibility in provided functionality should be shared between PSS provider and user. (EPEA NL) The subscription-like payment model of PSS opens the possibility for customers without the means for high initial investment to still enjoy the benefits of high quality products. While a subscription-like payment model for PSS improves accessibility of high quality is attractive to customers, this model poses a yet unresolved challenge: without complete upfront payment, manufacturers need credit to cover the costs (which it *does* need to pay upfront), and financial institutions are unlikely to accept movable products as collateral for this credit. (Connex, MVO NL)

PSS challenge the norm of ownership. People derive a sense of status and control from ownership, and this feature may impede PSS' acceptance. (Ceschin, 2013) (Tukker, 2013) (Tukker and Tischner, 2006)Not all customers want to have everything 'taken out of their hands' but prefer 'unconditionality of use' (Baines and Lightfoot, 2013)(Bartolomeo et al., 2003)(Wageningen University²) Companies need to investigate how their customers relate to the product and if they prefer unconditionality or ease of use. Also, manufacturers should assess the 'attachment' of their customers for new and in-fashion models of their products, since it may impede value extraction in a closed-loop PSS. (EPEA NL, Erasmus University, Wageningen University¹) (Tukker, 2013)

In literature, a discussion exists on consumers' propensity to ownerless consumption. Cook et al. (2006) state that consumers are becoming "increasingly amenable" to ownerless consumption, while Heiskanen and Jalas (2003) and Mont (2002) find it unclear what consumers' stance is on this development. The general opinion in the interviews was that the B2B market is more receptive to ownerless consumption than B2C. (Erasmus University, MVO NL, Wageningen University^{1,2}) The amenability of customers towards PSS may be influenced by a consumer's interest in the freshness and excitement that surrounds concepts like PSS. (Interface, Wageningen University²)

Summary

The key to PSS business success is found to be the provider's ability to identify the right contextual conditions for PSS. These conditions include characteristics of customer, product, legislation, and of the organization itself:

i) Product characteristics that qualify for PSS business model (Tukker and Tischner, 2006):

- Insensitive to fashion
- Easy to transport
- Costly
- Technically advanced
- Dependent on maintenance and repair
- Infrequently used by customer

ii) Customer characteristics: receptivity to PSS.

- B2B is more receptive than B2C
- Urban customers are more receptive than rural
- Young customers are more receptive than older customers
- Wealthy customers are less attached to ownership

iii) Legislation: understanding of firm behavior is limited, and providing the right incentives is complex.

- Environmental benefits are largely unproven
- Achieving effective incentives for firm sustainability behavior is complex: understanding is limited.
- Governmental systems (e.g. tax systems) are often oriented towards linear production and consumption

Organization: employee- and management culture needs to be open and conscious of strategic goals

- Intensified communication with customers and between firm departments
- Management culture shifts towards multi-term vision and flexibility
- Change in attitude of employees towards prioritizing service, product quality, recovery and retained responsibilities
- Realignment of performance incentives with strategic PSS goals

Literature and interviews have provided a starting point for exploration of conditions that impact PSS effectiveness both in terms of economic and environmental benefits. However, it has become clear that there are many facets to PSS development and that evidence and insight is lacking on many of these.

4.1.2 Closed-loop supply chain management

Four core themes were identified in the information from literature and interviews are: macro-context, recovery, market and competition, and internal organization. Again, these themes will be discussed sequentially, followed by a concluding remark. The theme of CLSC ontology is shortly discussed for completeness.

CLSC ontology

Contrary to the PSS concept, the ontology of CLSC management is well developed. No striking differences between definitions or classifications where found. The longer history of the concept and its origin in the operational management research field (perhaps more well defined than the origin of PSS) might be reasons for this difference.

Macro-context

Legislation is mentioned as a driver for CLSC activities in both literature and interviews. (Océ)(Dowlatshahi, 2000)(Dowlatshahi, 2005) (Ravi et al., 2005)(Toffel, 2004) Extended producer responsibility (EPR) is an important policy for CLSC and is implemented in many countries for product categories such as electrical and electronic equipment. EPR can be implemented as collective producer responsibility (CPR) or as individual producer responsibility (IPR). (Atasu et al., 2009)(Mitra and Webster, 2008) An advantage of CPR is the potential for economies of scale in collection and processing, but there are no incentives for individual manufacturers to change product design in favor of recovery. (Erasmus University)(Souza, 2013)(Spicer and Johnson, 2004) IPR incentivizes specialization in remanufacturing, increased efficiency and effective feedback between recovery and product design. (Spicer and Johnson, 2004) However, measuring the impact of collective and individual collection systems on product design is notoriously complex, (Souza, 2013) as are the reverse logistics of individual collection compared to a collective system, and the management orphaned products (imported products or products whose manufacturer has ceased to exist). (Spicer and Johnson, 2004) Finally, if they are to be operated cost-effectively, both collective and individual take-back systems may be 'intolerant' to imposed collection targets: targets impact cost-structures of disassembly companies, decreasing their profit margins. (Walther and Spengler, 2005) Moreover, the kind of target can impact the feasibility of recovery options: WEEE legislation emphasizes recycling and reuse, not remanufacturing, while remanufacturing may be the most sustainable option in certain markets (Wageningen University¹) In the interviews, the general disposition of legislation towards linear systems was noted. For example, end-of-waste criteria (determine when a material or object begins or ends to classify as waste) impact international transport of EoU or EoL products and materials. (EPEA NL, MVO NL, TU Delft, Spring Global Mail) Caterpillar, involved in remanufacturing activities, is lobbying to legally classify remanufactured products as "new", to facilitate international transport. (Caterpillar) Also, tightening RoHS legislation makes remanufacturing of older components (from a time where these components were legal) illegal. (Océ)(EU, 2011) This seems to expose a contradiction of goals in environmental legislation: hazardous substances are banned, making potentially environmentally beneficial remanufacturing impossible of products in the field. Governments should beware of these effects. For example, seeking input from mid-level managers of affected companies via lobbyists, governments could become aware of contradictory requirements quicker. Also, an overall vision on sustainability goals for governments could help prevent such antagonistic effects between policies. Suggestions for stimulating legislation are the taxation of materials use instead of labor (Interface) and the internalization of environmental costs (e.g. of energy investment in a product during production). (Wageningen University¹)

Closing loops of global supply chain loops is more complex than closing local supply chains loops, giving localized (and regionalized) production and consumption an advantage in this strategy. (DurabilIT, Océ) Also, 'local' recovery-oriented manufacturers compete in the market with global 'linear' players, who may have access to resources at much lower costs and much larger scale. (EPEA NL) This implies that localized production and consumption is a favorable condition for CLSC implementation, and that finding a market where competition from global players is low will decrease the cost pressure (until global players enter that market).

Recovery of value

The recovery of value out of EoU and EoL products is the core distinguishing feature of CLSC compared to traditional linear supply chains. As mentioned before, recovery is understood here in the broad sense of product acquisition, reverse logistics, inspection, reprocessing and remarketing. An additional aspect in literature and interviews found to be of relevance is product (re)design. Findings on these aspects of recovery will be described according to this division.

Product acquisition is the basis of CLSC activities, since without input the other processes are irrelevant. (Erasmus University, Spring Global Mail, Wageningen University¹) Moreover, without adequate quantities of returns at the right quality and price, CLSC are unable to release the 'latent' value from those returns. (Guide and Van Wassenhove, 2009b)(Toffel, 2004) An important factor in the success of acquisition of returns is the price incentive for the customer or any collecting party to return the EoU or EoL products. Pricing of returns is complex and depends on many factors, including the product wear, current abundance of returns, nature of the reverse network, product remanufacturability, and a product's "marginal value of time" (remaining value after a period of time). (Gupta and Palsule-Desai, 2011)(Morana and Seuring, 2007) Of course, in a lease-based business model the returns do not need to be purchased, and this arrangement greatly eases the acquisition of returns. (Océ)(Souza, 2013) A good relationship with chain actors was also mentioned during the interviews as an important resource to acquire returns. (Interface)

Acquired returns are collected and transported to the appropriate reprocessing facility. Generally, the agent in the supply chain closest to the customer is in the most suitable position to collect the returns (e.g. in a decentralized sales model, it is the retailer). (Savaskan et al., 2004)(Tibben-Lembke and Rogers, 2002) Using the right mechanisms, the manufacturer can incentivize that actor to save costs: with financial incentives, the manufacturer can elicit competition between retailers. (Savaskan and Van Wassenhove, 2006) Designs of RL networks can be divided in responsive and efficiency-focused networks. (Gobbi, 2011) A responsive network is considered more costly per processed unit, and whether these extra costs are justified depends on return rate, recoverable value per unit, costs and ratio of unusable products in the return flow, and value depreciation of used products. (Debo et al., 2006)(Guide et al., 2006) Efficient networks on the other hand outperform the responsive network in terms of costs and are appropriate if value depreciation with is not an issue. (Guide et al., 2006)(Krikke et al., 2003) Speed versus efficiency was also confirmed to be an important decision during the interview with the reverse logistics provider. (Spring Global Mail) The recovery network has a high impact on overall costs (compared to e.g. product design), so selecting the appropriate type of reverse network is paramount (Krikke et al., 2003) Finally, it should be noted that logistics parties traditionally focused on forward logistics might not have the right capabilities and channels to deal with reverse logistics. (EPEA NL, Spring Global Mail)

Literature suggests that assessment of the quality of returns and the logistics network should be designed together. (Beamon and Fernandes, 2004) Reliable inspection can negate uncertainty in the costs of remanufacturing. (Robotis et al., 2012) Product-specific knowledge was mentioned in the interviews is indispensable for effective assessment of quality of returns and warranty management (DurabilIT, PartTracker), and the (tacit) knowledge manufacturers have of their products puts them in a good position regarding this issue. (Pokharel and Mutha, 2009)(Toffel, 2004)

Product (re)design issues are frequently addressed in the context of CLSC in literature, since e.g. design-for-disassembly (DfD) can improve remanufacturability and hence extraction of value . (Giovanni, 2011)(Pokharel and Mutha, 2009)(Zuidwijk and Krikke, 2008) Also in the interviews, product-design was mentioned to affect especially

the higher forms of value recovery. (Erasmus University, Interface, Océ) Common redesign choices in CLSC include DfD and modular design, selecting durable and reusable materials, standardization and coding of materials and components, and increased content of recycled materials. (M. C. Thierry et al., 1995)

Regarding reprocessing, the emphasis in literature is mainly on remanufacturing. Remanufacturing is observed in product categories that feature durable products, technological products, refillable containers (e.g. printer cartridges) or recoverable materials (e.g. paper and glass). (Akçalı and Çetinkaya, 2011) Refillable containers and recoverable materials are attractive due to the perfect substitution between 'virgin' and recovered products, while technological products are replaced quickly and their residual value is often considerable. The majority of recoverable value of cell phones, per unit, is mostly contained in the product structure, and not in the materials. (Gever and Blass, 2010) In the interviews, this was confirmed to be the case and even generalized to apply to most products. (Erasmus University, Interface) The marginal value of time of durable products is relatively high, making the speed of the recovery process less important. (Akçalı and Çetinkaya, 2011) An issue addressed in literature and in the interviews was the heterogeneity of returns, which requires flexibility in reprocessing capacities. (Erasmus University, Océ) (Zuidwijk & Krikke, 2008) Being able to identify quality of returns early on in the recovery process contributes to dynamic recovery of value. (, Erasmus University, Océ, Spring Global Mail) A lease arrangement increases awareness of quality of returns, and this facilitates effective use of flexible processing capabilities. (Thierry et al., 1995)

Differentiating between remarketing in the context of recovery and the general aspects of market and competition that are covered in the next sub-section is challenging. It was decided that the impact of market dynamics on decisions regarding the recovery network is specifically relevant in the context of value recovery. The market diffusion speed of remanufactured products is constrained by diffusion of new products. (Atasu et al., 2008a)(Debo et al., 2006) (Inderfurth, 2005) The imperfect substitution of most reprocessed products on the other hand impacts the sales dynamics of new products (the cannibalization effect, which will be detailed in the next sub-section). (Debo et al., 2006) The reciprocal influence of marketed new and reprocessed products is a factor that makes effective planning and balancing complex, and research has only begun to scratch the surface of this issue of recovery. A useful perspective on this issue is the manufacturer as "fleet manager", where the fleet in use with the customer and the "buffer fleet" (returns and remanufacturable components) must be carefully managed and balanced. (Östline et al., 2008) The issue of interaction between new and reprocessed products in the market (the extent of which is likely to differ between products types) is illustrative for the complexity, sensitivity to context and reciprocal relations between processes in CLSC systems. Multiple authors note that providing generic design guidelines for CLSC systems is difficult due to the specificity of situations per product category and interactions between forward and reverse flows. (Wells and Seitz, 2005)(Akçalı and Çetinkaya, 2011)

In the interviews, cost of the overall recovery process compared to recoverable value was repeatedly addressed. This ratio should be considered when conceiving a CLSC to avoid over-investments in *individual* (compared to collective) recovery. This observation was regarded as applicable to the whole CLSC, not just logistics and reprocessing. (EPEA NL, Océ, Spring Global Mail, TU Delft)

An issue scarcely addressed in literature is that obsolescence of product components as a result of product innovation (or other minor adaptation) impedes full extraction of their potential value, since remanufacturing is impossible with obsolete parts. (MVO NL, Océ, PartTracker, Wageningen University^{1,2}) The same is true for

materials that were selected for durability and long life. This issue can be captured in a question of the 'locus of durability': should the product structure be made durable for extensive remanufacturing possibilities, or should only the material be made durable (possibly saving costs on manufacturing) so that parts can be quickly recycled and materials used again in new, technically more advanced parts? (MVO NL, Erasmus University) The answer to this question depends strongly on the nature of the product and its innovation rate, but also on the receptivity of customers to reprocessed products.

Market and competition

The receptivity of customers is a major precondition for (especially the higher forms of) recovery and reprocessing.¹⁰ Atasu et al. (2008a) note that industry knows little about consumer perceptions and valuation of reused or remanufactured products, and that manufacturers operate regarding this issue using mainly "common wisdom" instead of sound research. Also in academic literature, research addressing consumer attitude is often based on small 'lab' experiments and not on large surveys or repeated experiments among different groups of customers. Still, we will examine that literature in this subsection to give an impression of the state of knowledge in the field.

Souza (2013) notes that when offered a new product and a remanufactured product at the same price consumers opt for the new unit. However, when the remanufactured product is offered at a lower price, consumers infer a lower quality. Also, when a manufacturer offers a remanufactured product, the willingness to pay for new units decreases. This effect is weakened when a third party offers the remanufactured product. (Souza, 2013) Past experience and product knowledge also of consumers' perception of remanufactured goods. (Guide and Li, 2010) Interestingly, the 'weariness' of consumers towards recovered products appears to be less in the context of a leasing arrangement. (Robotis et al., 2012) Clearly, the perception of remanufactured products by consumers is complex and most probably dependent on the kind of consumer that is investigated (e.g. socio-cultural and economic situation, commercial or private).

Sensitivity of customers to changes in fashion and trends is mentioned as an attribute hindering the extraction of value from returns in CLSC. (MVO NL)(Tucker and Tischner, 2006) In the market where Caterpillar Inc. operates, functionality (e.g. labor per hour or cost savings per hour) is the unit of transaction. (Caterpillar) This situation can be considered the opposite of sensitivity to trend and fashion.

Consumers' discrimination between new and remanufactured products is of interest to manufacturers for the specific issue of market cannibalization; often mentioned in literature as one of the barriers for manufacturers to engage in CLCS. (Atasu et al., 2008b)(Debo et al., 2005)(Oraiopoulos et al., 2012)(Souza, 2013) Importance of the newness of products to customers was confirmed in the interviews (Erasmus University, PartTracker, Wageningen University¹, TU Delft), and some interviewees find that this customer need should be dealt with by fresh design or effective warranty management. (EPEA NL, Connex, Interface, PartTracker), Others find that this perception will and should change, since it impedes sustainable recovery practices. (DurabilIT, Spring Global Mail) In any case, CLSC practices must be effectively communicated to the engage 'sustainability-sensitive' customers. (Erasmus University, Océ, Spring Global Mail, Wageningen University²,) On the issue of cannibalization the interviewees rather shared each other's opinions: both academics and practitioners acknowledged the argument but were convinced that it was either abused to conclude the debate on remanufacturing, or that remanufacturing was part of customer

¹⁰ Recycling is not considered here since a product with recycled content is likely to be perceived by customers as a newly produced product

orientation and in that respect a certain degree of cannibalization may be tolerated. (Caterpillar, Erasmus University, Océ, Wageningen University¹) Some business tenders are even exclusively accessible with a certain ratio of remanufactured products in the offering. (Océ) Also the kind of market makes a difference on the distinction customers make between recovered and new products: B2B market is more receptive to reprocessed products than the B2C market. (DurabillT, Erasmus University, MVO NL, Océ, Interface, Spring Global Mail, TU Delft) This was also confirmed in literature. (Guide & Li, 2010) An important factor that makes B2B more attractive for CLSC is the lower amount of customers, and the higher degree of control over the conditions of the transaction. (Océ)

In literature, opinions on the relevance of cannibalization vary but generally agree that this issue can be overcome by strategic pricing (Atasu et al., 2008b)(Mitra, 2007) or even tolerated due to additional revenues of reprocessed products. (Oraiopoulos et al., 2012) Targeting different geographic markets with reprocessed goods can segment markets for new and reprocessed products. (Erasmus University, TU Delft,) And finally, the ability to retain existing customers by the customer contact at the 'handing over' of the return was noted during the interviews as well as in literature. (EPEA NL, Erasmus University, Océ, Polre Advisory, Spring Global Mail,) (M. C. Thierry et al., 1995)

Opportunity for cooperation between competitors was addressed both in interviews and literature. Developing an adequate recycling market benefits all competitors in the long term, since it ensures sufficient amounts of recycled materials of the right quality. Competitors could (temporarily) cooperate, e.g. to create critical mass for pushing certain material standards and increased capacity in the recycling sector. The same applies to non-competitors that have the same suppliers. (EPEA NL) Competition can be 'resumed' in other parts of the value chain. (Caterpillar, MVO NL, Océ, Wageningen University¹) (M. C. Thierry et al., 1995) Precompetitive research was suggested as an opportunity to cooperate by Thierry et al. (1995) but this was disconfirmed in the interview with Océ. (Océ) According to Toffel (2004) cooperation between competitors is only desirable if the driver for CLSC development is legislative pressure. If customer demand fulfillment is the driver for CLSC development cooperation with competitors may nullify advantage gained by developing valuable resources.

Within the theme of market and competition, interviews have often confirmed statements made in literature. Exceptions are the refuting of the risk of cannibalization and precompetitive research with competitors.

Internal organization

Product recovery requires drastic change in organizational capabilities, relations and structures.(Thierry et al., 1995) Companies need to develop "CLSC orientation": "an attitude that acknowledges the strategic implications of managing and integrating both the forward and the reverse flow". (Defee et al., 2009) Our focus points in this broad theme are information management, organizational structures and the strategic perspective.

The importance of information management is hinted throughout the many themes and concepts found in CLSC (and also PSS) literature. Concretely, performance of recovery is improved through a focused resource commitment to information technology (IT) capabilities. (Daugherty et al., 2005)(Jayaraman et al., 2008) It should be noted that capabilities with no direct relation to CLSC (e.g. total quality management) could also contribute to internal exchange of information between departments. (Toffel, 2004) As for PSS, also in CLSCs this internal harmonization of communication is necessary to extract value. (Caterpillar, Erasmus University, Interface, MVO NL, Océ, Wageningen University¹)

Since reprocessing is the activity in recovery that must be based on a combination of supply and demand information, the reprocessing actor is likely to be the center of supply-chain spanning information management systems. This observation is supported by findings in literature: Integration of information support systems across supply chain actors could improve efficiency for manufacturers. (Kulp et al., 2004)(Toyasaki et al., 2013)

Different types of information have a different impact on recovery performance (efficiency and effectiveness), and so information systems should be designed to collect and process the information that is most valuable to the specific recovery situation. For example, demand information is most valuable when demand variability, capacity availability and the holding costs per unit are high. (Ketzenberg, 2009)

Product use information (e.g. wear) and the reason for return are examples of information that can create value for manufacturers because they can be used in product improvement or marketing. (Océ Spring Global Mail, Caterpillar, Erasmus University) Feedback from the reprocessing departments to product design can improve reprocessability of products and hence recovery performance. For this kind of feedback, cross-functional management is found to be a facilitating capability (Océ)(Seitz and Peattie, 2004)(Toffel, 2004).

These non-financial forms of value should be accounted for in business models, since they can support profitable activities and/or strengthen the position of the company (e.g. reduced exposure to volatility in the materials market). (Erasmus University, Interface, Océ, Radboud University, Spring Global Mail)

As a more general information management capability, constantly 'probing' the environment was mentioned for identifying opportunities for cooperation. This is found to help both directly in increasing CLSC effectiveness, and in heightening awareness in the environment on the firm's CLSC activities. (Interface)

Besides information management, other internal organizational structures are likely to change in CLSC compared to traditional linear chains. For example internal accounting structures should avoid inefficiencies like double cost counting: counting the entire costs of initially manufacturing the product as the input costs of remanufacturing (while instead only the costs of acquisition and logistics were incurred). (Toktay and Wei, 2011). Classifying products as 'waste' in the company accounts also influences what legislation applies, and thus the (feasible) possibilities for recovery. (Interface, Wageningen University¹) And internal pricing of components can influence designers' behavior regarding use of recovered parts: lower internal pricing of those parts might help overcome designers' (often irrational) preference for new parts. (Erasmus University, Wageningen University¹)

The background of many employees may not equip them to independently devise the most effective solution for the overall goals of the CLSC. (Spring Global Mail) However, their professional knowledge can be used to strengthen the case of CLSC, and therefore they should be involved early in the development of the CLSC system. Connected to this is the realignment of performance measurement and operational and marketing practices with the overall goals of CLSC as well. (EPEA NL, Erasmus University, Océ)

The final aspect of internal organization relates to the strategic perspective on CLSC. CLSC is often regarded with a 'damage control' perspective instead of a 'source of value' perspective. (Atasu et al., 2008a)(Mondragon et al., 2011), According to Bell et al. (2012), also academic literature scarcely addresses possible benefits of CLSC beyond legal compliance and cost savings. A strategic vision that puts the CLSC approach into

perspective (e.g. pre-empting negative effects of (future) resource scarcity), and reflects short-term benefits and long-term goals, can also be an effective tool to guide everyday practices towards desirable behavior in CLSC. (EPEA NL, Interface, Océ) The importance of a vision for making concrete employee behavior more effective illustrates that the integration of forward and reverse flows requires internal cultural and structural changes, besides the more obvious technical changes. (Seitz and Peattie, 2004)

Summary

Maximizing value creation throughout the chain and recovery of value are the important elements of CLSC. Key to achieving these two goals are found to be:

- Sharing of information within the chain and the organization
- Accounting for non-financial forms of value (relational, informational). Since in CLSC the communication within the chain and organization is intensified, these forms of value are expected to be significant. Of course, the manufacturer must assess the advantage gained from these forms of value compared to any costs made in obtaining them.
- Thorough investigation of the complex customer perceptions of reprocessed products to find the right market.
- A company culture that prioritizes product quality, service and openness within the organization, to customers and to other chain actors.

Important other characteristics of CLSC are:

- Managing reciprocal relations: for example, market dynamics of new and recovered products may influence each other, and since new products are the input for reprocessing, this influence must be managed.
- Integrated design of the network: the design of one part of the network (e.g. reverse logistics) must be informed by other departments (e.g. accounting, marketing and remanufacturing). For example: whether a recovery network should be efficient or responsive depends on product features like rate of value depreciation, recoverable value per unit, and extent of substitution between reprocessed and new products.

An important open question is exposed by examining the theme of innovation in CLSC and PSS: in PSS quick innovation is required and stimulated to deliver better or more efficient functionality, while innovation in CLSC makes products and parts obsolescent which reduces the potential for value extraction (especially since product structures, not materials, are found to contain the most recoverable value). If and how these contradictory requirements impact closed-loop PSS is an interesting topic for further research.

4.2 Relation between linear chains and closed-loop PSS

Based on the analysis in section 4.1, the relation between linear chains and requirements for closed-loop PSS can be examined.

From a sustainability perspective, there is a big difference between linear supply chains and closed-loop PSS. For example, if a product is made to last for 200 years it will generate revenue once in that time for a 'linear manufacturer' and continuously in the case of a PSS. Also, in a closed-loop PSS discarded products can be remanufactured so that production of a new unit can be postponed even longer. This implies that in linear

chains there is no incentive to create products that are more durable than the absolute minimum that is still acceptable for the consumer.

These different incentives for pushing product volume relates to the difference in 'side-effects' of innovation in linear and closed-loop systems. In linear chains, innovation often results in the consumption of new and improved products. Because of this, still functional products become obsolete and are often discarded. The side effect of innovation in linear chains is therefore purchase of new products, which is in the interest of a linear manufacturer. In closed-loop PSS, innovation ensures that functionality is improved or delivered at lower costs (economic or environmental): a goal of PSS. However, the replacement of obsolete but functional products causes a different side-effect: impediment of maximum recovery of value from these obsolete products. This negative side effect of innovation can be managed by accurately segmenting markets: products that become 'second-best' through innovation can be used to serve customers that have lower requirements. In this way the value remaining in the obsolete products can still be extracted.

To recognize these possibilities to maximize value creation, it is required to develop strong communication in the chain, with customers and between departments in the organization. Non-financial forms of value, such as information about product use and customer loyalty, are accessible because of this strong communication. Closed-loop PSS have a high potential for creating these kinds of value and manufacturers should therefore be aware of this possibility. Communication between actors in linear chains is hesitant because of the fear to lose informational advantage over others, so manufacturers who aim to create value creation closed-loop PSS must deal with the hesitation of other actors to share information. Also, current actors for certain functions may lack capabilities needed for effective functioning in closed-loop PSS. For example, collecting waste in current linear systems is a fundamentally different activity than collecting EoU and EoL products and dynamically distributing them to enable maximum recovery of value. Manufacturers must be aware of the changing requirements for actors and evaluate whether to cooperate with other, more appropriate actors or jointly develop new capabilities.

Openness in sharing information between departments and recognizing nonfinancial forms of value is part of a change in company culture required for effective closed-loop PSS development. This change of perspective can be illustrated using the problematization of cannibalization; an issue mentioned frequently in literature and interview. If maximum value creation of the whole CLSC is the goal of every actor and department, consumption of reprocessed products at the expense of virgin products will be judged based on its contribution to total value creation, and not on its reduction of virgin product sales as is often the case. The perspective on sources of value and on total creation of value instead of 'compartmentalized' creation of value (per department) is an important point of differentiation between linear chains and closed-loop PSS.

In general, the relation between linear chains and closed-loop PSS is characterized by a change in perspective on sources of value and increased sharing of information which must happen both in the organization of the manufacturer and other actors within the chain.

4.3 Strategic considerations

The results of comparing and contrasting interviews and literature are used as a basis to assess the strategic considerations encountered when a manufacturer considers implementing CLSC and PSS. We refer the reader to section 2.3 for an explanation of the three strategic management concepts that make up the assessment framework used in this section (resource-based view, strategic positioning and co-alignment of organization and environment).

4.4.1 Resource-based view

Implementation of both PSS and CLSC is very dependent on context in terms of product, customer, organization and legislation. Pinpointing specific firm resources that produce sustained competitive advantage (VRIN resources) is not possible in this research due to the lack of a concrete case study. As mentioned in section 4.1, the impact of PSS on competitive advantage is unclear: statistics even suggest the possibility of negative impact on competitive advantage. Therefore, this section will remain on the level of general firm characteristics and resources that are *likely* to increase PSS effectiveness, and characteristics of PSS that are *likely* to produce competitive advantage. For manufacturers implementing PSS and CLSC, these two concepts/approaches are considered resources.

The four characteristics of firm resources (value, rarity, imperfect imitability and non-substitutability) will provide the structure for this section. For a description of the meanings of the four criteria, the reader is referred to section 2.3 (Table ... specifically).

Value

Barney (1991) appears to equate firm attributes that are considered a resource (allowing the firm to take advantage of opportunities and to neutralize threats) with valuable resources. Valuable resources allow a firm to implement a strategy that improves its effectiveness and efficiency. Hence, we will focus on whether CLSC and PSS allow firms to exploit opportunities and counteract threats in the environment.

CLSC provides a suitable framework for manufacturers to address (impending) natural resource scarcity and (possibly, depending on the implementation of the policy) EPR legislation. PSS lets manufacturers capture value "downstream" the supply chain and increases potential for innovation and differentiation, especially in mature markets. A more intense customer relationship (compared to regular sales of product) allows for accurate assessment and fulfillment of customer needs, and increases the likelihood of recurring revenues through repeated 'purchase' of functionality.

Not all customers are receptive to ownerless consumption, and the conditions of PSS contracts are likely to influence this receptivity as well. Manufacturers need to clearly identify with which customers and products they can exploit opportunities using PSS. Also, the effect on PSS profitability of the general legislative orientation towards linear systems (e.g. tax system) has to be assessed.

The contribution of specific firm resources to valuable PSS and CLSC is likely to depend on the whole system: the same resource may contribute strongly to value of PSS in some cases, and only marginally in others. To identify specific resources that generally contribute to valuable PSS, and the conditions that determine the extent of the contribution, a large number of similarly performed case studies is required.

Rarity

For the purpose of this research it was assumed that, given the general rarity of CLSC and PSS in many markets, implementing the concepts would in many cases provide the implementing firm a rare 'resource'. Ownerless consumption is far from the

norm as are recovered products. The question arises however if the rarity of the concepts in practice is best explained by their strong context dependence and that, in many cases, they are simply not feasible, or if rarity is explained by the failure of many firms to see the opportunity. This interesting question is beyond the scope of this research.

Imperfect imitability

Imitating specific, individual resources (which may appear to be the main cause of success of a PSS) is a weak strategy for competitors, since it is the fit between resource and context (environment and organization) that produce effective PSS. For the same reason it is a weak strategy for manufacturers to focus on developing only a few resources (this will be described in the subsection "Strategic positioning").

For example, an information management system built to effectively collect and process a certain type of information that is valuable in its specific context (e.g. because it helps anticipate demand variability) may be imitated by a competitor, but the pay-off of this system is likely to be lower in a different context. Other contextual factors that determine the fit of a specific resource are described in the 'Summary' of sections 4.1.1 and 4.1.2. Value-creating PSS and CLSC are characterized by sensitivity to these contextual factors, and therefore a value-creating implementation of these two concepts is likely to be hard to imitate.

Non-substitutability

Regarding the potential of CLSC to address natural resource scarcity, there are a number of alternatives and variations to the closed-loop approach. Strongly developed collective collection systems and recycling markets could omit the need for manufacturers to recover products, although value recovery through reuse and remanufacturing would then not be possible. However, the influence the individual manufacturer has on this development is unreliable. If the manufacturer is seriously concerned about effects of volatile material resource prices, the reliance on nationwide developments seems a doubtful strategy. On the other hand, closing global supply chain loops may be even more complex and unreliable. In the interviews the possibility of planning on multiple time-horizons was stressed. Manufacturers can invest in closed-loop systems, after which the large-scale development of the recovery market should be pursued to achieve economies of scale. (EPEA NL) In any case, the customer needs to be receptive to the idea of consuming reused and remanufactured products, since higher order recovery options are an important condition for CLSC feasibility.

The combination of product and service in PSS is a unique and novel proposition that offers different value than the traditional product sales proposition. The customer experiences more flexibility in terms of functionality that he/she can consume. The key is to clearly identify and target the customers that are receptive to ownerless consumption. For customers that are skeptic, flexibility in contractual conditions of use may be a solution, although this flexibility is likely to increase costs of the PSS. Access to high quality products without high initial investment may be already possible with regular leasing, but the possibility to achieve higher margins with lower energy consumption and more durable products provides a unique incentive to manufacturers to invest in the products they 'deploy' to provide functionality.

The value and non-substitutability of PSS and CLSC depends on customer-, product-, organizational-, and legislative characteristics. However, if a manufacturer manages to identify 'fertile ground' for PSS and CLSC, context-dependence makes the concepts imperfectly imitable. Also, the general rarity of PSS and CLSC is likely to contribute to 'sustainability' of competitive advantage gained through implementing these two concepts.

4.4.2 Strategic positioning, trade-off and fit

The contribution of PSS and CLSC to sustained competitive advantage in the perspective of Porter (2000) is discussed in this section. The three requirements for sustained competitive advantage are clear strategic positioning, trade-offs with other strategic positions, and strategic fit between activities. These three aspects are discussed in turn.

In CLSC literature, the high uncertainty that characterizes the returns in CLSC is described as a major issue that challenges the system's feasibility. Porter's distinction between needs-based positioning and access-based positioning may shed new light on this issue. When a manufacturer in a CLSC serves all customers who *want* to use the product, the recovery network has to accommodate returns with a great variety in quality, volume and timing. This (at least in part) is likely to generate the uncertainty observed as an issue in CLSC. This implies that manufacturers who pursue cost-effective CLSC should make the following decision: serve a segment of customers based on their needs and face the high (and costly) uncertainty, or select a (potentially smaller) group of customers according to their attributes to gain more security and predictability. This also suggests that manufacturers already operating in this way may have an advantage in implementing CLSC over manufacturers with a different kind of positioning.

Interestingly, although customer needs orientation appears to be prominent in the PSS concept, this does not have to conflict access-based positioning. In the industry of high value capital equipment, a limited range of products is complemented with a broad range of complementing services. (Baines et al., 2007) By serving customers with certain attributes and offering a limited range of products (satisfying the need for predictability in CLSC) with a broad range of complementing services, a relatively high customization can be achieved without a proliferation of types of returns (which may drive up costs). Porter also notes that major structural changes in industry give rise to new strategic positions and that they are also important reasons for companies to change their own strategic position. Companies that are unburdened by structures and inertia arising from the firm's history often more easily exploit the new strategic positions. This may be a reason for the success of small firms in implementing PSS.

According to Porter, positioning is always based on differences between competitors on the supply side (firm activities) and possibly also on differences on the demand side (customers and their needs). Whether a manufacturer's strategy is based on needs or access on the supply side, to build a strong strategic position is always based on differences in firm activities. PSS and CLSC require change in many elements of a firm and its chain (culture, structures, product, relations in the chain and with the customer, and business models), and these elements must be *designed* to fit together. Porter states that any activity that is "overdesigned or under-designed for its use" destroys value, and this is especially true for PSS and CLSC. For example: suppose a manufacturer imitates an elaborate information management system that is implemented by a competitor that recovers its products. If the imitator does *not also* invest in imitating other practices of the competitor (e.g. adequate acquisition), the information management system is "overdesigned for its use" and value is destroyed, making the imitation a weak move. Also, changes in firm culture are generally slow and resource-intensive, and are hard to

Also, changes in firm culture are generally slow and resource-intensive, and are hard to copy. All three of these characteristics imply a strong trade-off with other positions. Both concepts, and certainly both combined, are found to require strong trade-off with other positions to be effectively and successfully implemented.

The potential for strategic fit of CLSC and PSS is quite pronounced. Porter distinguishes three "orders" of fit:

- First-order fit: Consistency between strategic goals and activities
- Second-order fit: Reinforcement between activities

• Third-order fit: Optimization of effort.

(Especially second- and third-order fit are defined as essential to sustained competitive advantage).

First order fit is addressed in PSS and CLSC through the need for a consistent long-term vision that both provides guidance to face issues like (impending) natural resource scarcity and helps diffuse the principles of PSS and CLSC in the organization and in the chain. The many open questions regarding PSS threaten the consistency (and hence the effectiveness) of this long-term vision.

The potential for second order fit is evident: for example investment in information management improves logistics performance and 'fleet management' of products. This is a clear attribute of fit between activities: "improvements in one activity will pay dividend in others". (Porter, 2000)

The most basic type of third order fit is "coordination and information exchange across activities to eliminate redundancy and minimize wasted effort" (Porter, 2000). Product improvement through information feedback between recovery and design could classify as third order fit since it aims at minimizing wasted effort in terms of recovery and customer value.

Based on the three elements of positioning, trade-off and fit, we can conclude the following:

- Access-based positioning is likely to alleviate the high uncertainty of CLSC
- The strategic position of the CLSC and PSS approach requires significant tradeoff with other strategic positions because of high need for fit and cultural change (compared to the product sales model)
- Fit is an integral part of CLSC and PSS development, and thus these activities contribute to sustained competitive advantage.

4.4.3 Co-alignment of organization and environment

As a final strategic management perspective on closed-loop PSS we use coalignment of organization and environment by Bourgeois (1980). Since this research does not deal with specific cases, statements made here about co-alignment will be limited to general resources, similar to the approach in the subsection on the resource-based view.

Changes in the task environment that may move the manufacturer to realign with it include increasing and more volatile resource price, a saturated market, and EPR legislation.

The process of (re)aligning an organization with its environment is unique in every case. And in every scenario, adequate information about the environment is essential to successful alignment. However, PSS seems to be more dependent on accurate insight and pinpointing of customer needs than a product sales business model. This also applies to customers' receptivity to recovered products in CLSC. Because the PSS concept and its relation to regulation are still developing, proper scanning of legislation and any impending changes therein is required to ensure alignment of PSS with its environment.

Setting objectives will expand from minimizing costs and short-term risks to maximizing value creation, which can include non-financial value like relations or information. Also a more focused targeting of customers may occur, based on receptivity to ownerless consumption and requirements for a CLSC.

Distinctive competences that are likely to be valuable in a closed-loop PSS are "harmonized" internal- and chain communication, effective assessment of customer needs and relation with the product, and the ability to recognizing multiple sources of

value. Manufacturers must pay special attention to fit between *all* activities and not focus too much on distinctive competences.

In closed-loop PSS, mechanisms for resource allocation also have to account for these multiple sources of value and not be deceived by lacking direct revenues. The same applies to monitoring and control systems. Most probably there will be higher transaction costs due to the intensified communication and coordination between actors in the chain.

The three perspectives on CLSC and PSS in terms of strategic significance have produced an impression that the two concepts can be strategically very significant due to imperfect imitability and the strong requirement for trade-off and fit. However, investigating co-alignment between environment and organization will reveal whether the environment is receptive to these concepts and thus determine whether the strategic position achieved with CLSC and PSS will produce sustained competitive advantage.

4.4 Complementarity of PSS and CLSC

In this section a line of argument is presented that underpins the thesis that the concepts of CLSC and PSS are complementary.

Firstly, the attention to kinds value other than financial in the CLSC research field could open up new perspectives in the PSS field on what kinds of value can be gained from a contractual agreement. Also the recognition that value of products and materials can be extracted over multiple lifecycles, as well as the awareness of contextual factors on which this potential depends, is stronger in the CLSC field than in the PSS. These perspectives might strengthen the business case for PSS. Also, 'closing the loop' contributes to actualizing the potential (and expected) environmental benefits that form an important reason for the amount of attention paid to the concept. Literature also mentions that profitability of a PSS depends on physical attributes of the product such as durability, and the CLSC field has a lot to offer in terms of specifics of and interrelations between these kinds of operational and design issues (e.g. product attributes and network characteristics).

In the CLSC field there are discussions on the major issues of customer acceptance of recovered products and the potential for market cannibalization of new products by recovered products. In a number of ways, the PSS business model addresses these problems. Customers' distinction between new and recovered products is shown to be less in a leasing arrangement. It should be noted that this distinction might be even more reduced in PSS, because of the focus on functionality instead of products. Substitutability between new and recovered products is thus higher, although it is questionable whether it could be called perfect substitution. In a PSS, a customer pays for functionality and whether this is provided by a new or a remanufactured product (supposedly) makes no difference, eliminating the basis for concern over cannibalization. In fact, the PSS provider benefits from providing the same functionality with a remanufactured product since it can charge the same price while incurring fewer costs of production. This circumstance favors reuse and remanufacturing, which is, according to CLSC literature, also the source of the majority of recoverable value in returns.

The CLSC field emphasizes the importance of acquiring adequate quantities of returns. Leasing facilitates CLSC management in a number of respects. Companies that lease their products generally have more information on the quality of the returns, making it possible to predict changes in input quality (and quantity, since the end-date of a contract is known) and adapt the recovery network accordingly. Related to this, the balancing of new and recovered products that are out 'in the field' with the customer, essential for a steady supply of reprocessable returns, is easier in a leasing context. Also, the provider remains the owner of the product, thereby eliminating competition by third

parties for the returns. Competition for returns with third parties is considered detrimental to the capacity for value recovery in CLSC and is believed to disincline manufacturers to implement design improvements that facilitate value recovery. The latter aspect makes PSS congruent with the goals of EPR policy: reduction of waste and incentivizing eco-innovation.

Finally, in both fields the requirement for change in company culture and structure, communication, performance incentives and business models is emphasized. The concepts are both also highly context-dependent and in that sense hard to copy or graft from one context into another.

Judging from the abovementioned aspects, the CLSC and PSS research fields could benefit from exchanging their knowledge and challenges. Of course, the fields will never completely overlap (there will be CLSC without leasing arrangements and PSS that are not 'closed-loop') but where they do overlap there may be potential for mutual reinforcement and problem solving. Also, manufacturers can be expected to benefit from implementing PSS and CLSC together.

5. Discussion

Due to numerous factors, this research had to deal with limitations. Important limitations are the compiled assessment framework for strategic significance, unsystematic differentiation between different types of literature, no statistical analysis and triangulation of interview data, and the lack of a specific case study of combined implementation of PSS and CLSC. These limitations are discussed below. Also, some important remaining questions in the fields of PSS and CLSC research are discussed.

An assessment framework was compiled to arrive at a more comprehensive view on the strategic significance of CLSC and PSS. However, the validity of this particular combination of perspectives may be debated. This combination of perspectives was formed not on the basis of exhaustive literature research but by using an educational study book as a reference point. However, since this research aims to explore strategic significance of CLSC and PSS, and not to examine the strategic management field by providing an all-encompassing framework, this approach seems justified.

Part of the findings in the examined literature is grounded in empirical evidence, part is grounded on modeling work, and part of the literature was of a conceptual nature. The different research methods are not addressed systematically in this report, but rather in places where the implications of the research method on the findings was obvious to the researcher. A systematic analysis of the research methods in the articles may reveal more knowledge gaps in PSS and CLSC. Actually, Atasu et al. (2008a) address and warn for the institutionalization of assumptions (e.g. perfect substitution between new and reprocessed products), so generation of more empirical evidence of PSS and CLSC seems an important point for the research agenda.

Also, the empirical data in this research was not triangulated. In the semistructured interviews, only when it seemed appropriate were attempts made to confirm or disconfirm a statement made in another interview. This may weaken the strength of the empirical findings.

This research represents the empirical data as individual opinions without statistical analysis. This is justified because of the exploratory nature of the research: the goal is to begin mapping the implications of PSS, CLSC for strategic management. Triangulation of interview data was also not performed. The aim to represent a broad spectrum of opinions and statements mad this kind of rigorous checking unfeasible, given the time constraints of this research. It should be noted that the premise of mapping strategic implications for PSS and CLSC might have been overly ambitious for the scope of this research. Reliably analyzing contributions of firm resources to competitive advantage is complex even in a single case study, but to generalize these findings to recommendations for manufacturers is a great simplification in this case. The strong reliance on context of PSS and CLSC makes reliably identifying VRIN firm resources or strong strategic positions in closed-loop PSS certainly beyond the scope of this research.

The limitations in rigor make that the findings of this research should be considered as an attempt to create an overview: putting opinions and findings from literature into perspective and trying to point out important open questions.

Besides insights, the analysis has yielded several open and important questions in the PSS and CLSC research fields:

- What are the implications of PSS on government structures such as tax systems? And how does uncertainty regarding these implications impact pioneers in closed-loop PSS?
- How can government create effective incentives for sustainable behavior of firms in PSS?
- What characterizes customers that are receptive to ownerless consumption?
- What are actual environmental gains of different types of PSS, and what is their extent?
- What is the effect of servitizing on manufacturers' competitiveness?
- What traits/changes in company culture have facilitated successful servitized firms?
- Do PSS have implications for organizational science and, if so, what are they?
- Are the roles of innovation in PSS and CLSC contradictory? How does this impact closed-loop PSS?
- What is the role of CLSC in a context of advanced (inter)national recycling infrastructure? And what are differentiating factors between closing global and local supply chain loops?

These questions can be used to guide future research.

6. Conclusions

Firstly, it is appropriate here to repeat that this exploratory research provides a preliminary overview, reveals interesting questions and avenues of research, and thereby stimulates more specific research on these questions. The goal is not to provide a definite and exhaustive overview of all strategic considerations regarding PSS and CLSC for all possible manufacturers.

The first sub-question of this research asks for characteristics of PSS and CLSC. An important characteristic of CLSC and PSS is that both concepts are very sensitive to context. The receptivity of customers is far from mainstream for both CLSC and PSS and thus for both concepts a very accurate assessment for 'fertile ground' must be made. However, if ownerless consumption is accepted among customers, their discrimination between new and reprocessed products fades, facilitating value recovery in a closed-loop setting. A product characteristic that impedes value creation in both concepts is the sensitivity to fashion, and the underlying risk is product obsolescence. Because of this, the role of innovation in a closed-loop PSS seems unclear: PSS facilitates innovation, but innovation can impede value creation in a CLSC.

Another characteristic of both concepts is the need for dynamism to create value: the uncertain patterns of product returns and the need to customize and respond to customer demands necessitate a high degree of responsiveness to create maximum value. Information exchange within the manufacturer's organization and between chain actors facilitates this dynamism, but it also bears costs and the magnitudes of costs and benefits is likely to differ strongly between cases.

The potential for the creation non-financial forms of value is high in both PSS and CLSC: customer loyalty and opportunities for product improvement through analysis of returned products can provide a basis for advantage that is difficult to compare with financial value, but should be accounted for nonetheless.

The potential impact of pressures from governmental actions is strong for PSS and CLSC. The lacking understanding of firm's sustainability behavior makes the creation of effective incentives complex and the risk of inaccurate incentives is destruction of value. Related to this is the lack of evidence for PSS' environmental benefits. The incentive for sustainable production and consumption that is generally expected from the two concepts is certainly there potentially. However, it seems that this incentive depends on factors like who the PSS provider is (manufacturer or another actor), and the details of what creates the right incentive are yet unknown. Based on this research, it can be stated that closed-loop PSS are only a partial answer to achieving 'lowcost sustainability' for society (compared to enforcement). In the cases where closedloop PSS is not expected to create value, other concepts or enforcement is still needed.

A final important characteristic of the PSS concept is its still developing ontology. Classification systems offer room for nuance and a fundamental debate issues like the nature of functionality actually and implications for business culture in general may expand the field's focus even further. The ontology of CLSC seems to be more advanced, and it might give the PSS component of a closed-loop PSS some necessary structure.

The second question is regarding the relation between linear chains and the requirements for PSS and CLSC. The potential for non-financial value creation is a clear differentiating factor. The ability to create much informational value and maintain long-lasting customer relationships is harder to achieve in a linear chain. However, the cultural change in organization and chain required for a closed-loop PSS is likely to be resource intensive and time consuming. Employees need to prioritize (product) quality, service-mentality, and recognition of different types of value. Company structures need to be adapted to reflect and reward these new requirements.

Actors currently involved in the collection of waste or distribution in general may not (yet) possess the capabilities required to function in a value creating closed-loop PSS. This is related to the shift in perceived sources of value that needs to occur in the whole chain.

The final question of this research considers the impact of PSS and CLSC on competitive advantage. This has been found to depend on product-, customer-, organizational- and legislative conditions, but the fact that these systems can be considered generally hard to imitate and rare makes their contribution (*if* they are implemented) to sustained competitive advantage likely. Tight integration within the organization and between actors required for value creation are causes for this imperfect imitability. Through access-based positioning, the issue of uncertainty in CLSC is likely to be reduced. Also, the strategic position of closed-loop PSS require significant trade-off with other strategic positions, and partial imitation by competitors can be considered a weak move. In general, the organizational objectives of manufacturers must expand to represent the multiple sources of value discussed above. Consequently, more resources

are likely to be spent on transaction costs and support systems that facilitate value creation.

The concepts of PSS and CLSC can be considered complementary based on the analysis in this research. For example, the fact that the issue of cannibalization is irrelevant in PSS means that CLSC researchers may closed-loop PSS an interesting case to research, while the specific knowledge on impact of product characteristics on value recovery in the CLSC field can inform and strengthen the PSS business model. Joint implementation of these two concepts by manufacturers can be considered advantageous for manufacturers in the respect that both require a change that is likely to be of a similar magnitude.

Recommendations for further research following from this research include the impact of international product and material flows and collective recycling infrastructures on CLSC and PSS and the interactions between them. Also, implications of the PSS business model on organizational science and governmental systems like the tax system are interesting and fundamental questions which can help form PSS ontology. Developing evidence for actual environmental benefits (or detriments) of PSS and the concept's contributions (or negative impact) on competitive advantage is a currently under addressed aspect in PSS research that nonetheless can greatly facilitate e.g. the creation of effective governmental incentives. Systematic and large-scale customer research on characteristics that determine receptivity to ownerless consumption would especially aid manufacturers and firms in general that aim to assess the suitability of their context for closed-loop PSS. And finally, behavioral patterns of firms that impede sharing of information and how this issue can best be managed seem to be more interesting organizational science questions that can shed light on a facet that seems to underlie both concepts: the need for parties in a closed-loop PSS to entrust one another with their profitability.

7. References

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General search settings in Scopus:		Comments: • Relevance of articles was judged on article title and						
Search in Article Title, Abstract and Keywords								
	Sorted by	"cited by"		abstract				
a a				Not all articles we	re used in the r	eport	î	7
Search term	"product-service system"	"product-service system" AND "business strategy"	"product- service system" AND "competitive advantage"	"closed-loop supply chain"	"reverse logistics"	"business strategy" AND "closed- loop supply chain"	"competitive advantage" AND "closed-loop supply chain"	
Search limitations	Articles, reviews	Articles and reviews	None	Journal articles and trade publications	Journal articles and trade publications	None	None	
	Exclude subject areas: Energy, Chemical engineering, Arts			Articles, reviews, articles in press	Articles, reviews, articles in press			
	and Humanities, Medicine, Earth and Planetary science, Computer science, Physics and Astronomy, Agricultural and			Exclude subject areas: Energy, Chemical Engineering, Agricultural and Biological Sciences, Arts and Humanities, Computer Science, Physics and Astronomy				
	Biological sciences, Health Professions			Disregard papers without citations	Regard top 10% of all results			Total (excluding 5 duplicates):
Articles	117	33	14	201	76	16	8	465
evaluated								
Selected	26	12	1	56	27	8	4	129

Appendix I – Details literature survey

Final queries in Scopus	
Search term	Query
"product-service system"	TITLE-ABS-KEY("product-service system") AND (EXCLUDE(SUBJAREA, "COMP") OR EXCLUDE(SUBJAREA, "ENER") OR EXCLUDE(SUBJAREA, "AGRI") OR EXCLUDE(SUBJAREA, "COMP") OR EXCLUDE(SUBJAREA, "ENER") OR EXCLUDE(SUBJAREA, "AGRI") OR EXCLUDE(SUBJAREA, "MEDI") OR EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "EART") OR EXCLUDE(SUBJAREA, "HEAL") OR EXCLUDE(SUBJAREA, "PHYS") OR EXCLUDE(SUBJAREA, "EART") OR EXCLUDE(SUBJAREA, "HEAL") OR EXCLUDE(SUBJAREA, "HYS") OR EXCLUDE(SUBJAREA, "MEDI") OR EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "AGRI") OR EXCLUDE(SUBJAREA, "MEDI") OR EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "AGRI") OR EXCLUDE(SUBJAREA, "HEAL") OR EXCLUDE(SUBJAREA, "PHYS") OR EXCLUDE(SUBJAREA, "HEAL") OR EXCLUDE(SUBJAREA, "PHYS")) AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT- TO(DOCTYPE, "re")) AND (LIMIT-TO(LANGUAGE, "English"))
"product-service system" AND business strategy	TITLE-ABS-KEY("product-service system" business strategy)
"product-service system" AND "competitive advantage"	TITLE-ABS-KEY("product-service system" "competitive advantage")
"closed-loop supply chain"	TITLE-ABS-KEY("closed-loop supply chain") AND (EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "ENER") OR EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "ENER") OR EXCLUDE(SUBJAREA, "ARTS") OR EXCLUDE(SUBJAREA, "AGRI") OR EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "ARTS") OR EXCLUDE(SUBJAREA, "AGRI") OR EXCLUDE(SUBJAREA, "CENG") OR EXCLUDE(SUBJAREA, "ENER") OR EXCLUDE(SUBJAREA, "ARTS") OR EXCLUDE(SUBJAREA, "AGRI")) AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT- TO(DOCTYPE, "re")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "d")) AND (LIMIT-TO(LANGUAGE, "English")) AND (EXCLUDE(SUBJAREA, "COMP") OR EXCLUDE(SUBJAREA, "COMP") OR EXCLUDE(SUBJAREA, "PHYS") OR EXCLUDE(SUBJAREA, "PHYS"))
"closed-loop supply chain" AND "business strategy"	TITLE-ABS-KEY("closed-loop supply chain" business strategy)
"closed-loop supply chain" AND "competitive advantage"	TITLE-ABS-KEY("closed-loop supply chain" "competitive advantage")

Appendix II – List of interviewees

Organizations	Description of organization	Function interviewee
MVO Nederland	Business networking organization for	Senior program manager
	corporate social responsibility	planet
		1
Polre Advisory	Advisory firm for sustainability strategies	Partner
Spring Global Mail	International commercial mail service provider. Reverse Logistics Division	Global product marketing manager
PartTracker	Intermediary/trader of industrial machine parts	CEO
Océ / Canon Nederland	Manufacturer of professional printers	Manager asset recovery and remanufacturing
DurabillT	Independent supplier of used networking hardware	Managing director
Connex	Manufacturer of office interior elements and power strips	Owner/director of strategic marketing & new business
EPEA Nederland	Consultancy on and certification of Cradle- to-Cradle products	Managing director
Caterpillar	Manufacturer of commercial heavy machinery and engines. Remanufacturing department	Reman commercial manager
Interface	Manufacturer of commercial modular carpet tiles	Sustainable Business Development
Wageningen University ¹	Chairgroup Logistics, Decision & Information Science	Associate Professor, number of publications of reverse logistics
Wageningen University ²	Chairgroup Environmental Policy	Associate professor, number of publications on greening consumption
Erasmus University Rotterdam, Rotterdam School of Management	Closed-loop supply chains (CLSC) centre	Scientific Director
Technical University Delft, Faculty of Mechanical, Maritime and Materials Engineering	Knowledge Platform Sustainable Materials Management	Secretary and initiator
Radboud University Nijmegen, Nijmegen School of Management	Departments of Business Administration and Innovation Management	Professor

Appendix III – Interview protocol

Interview protocol used when interviewing firms

Introduction

- Would you agree if we record this interview for purposes of this research?
- Introduction of the research goals, and the purpose of the interview
- Explain why we approached the interviewee
- Introduce Turntoo and the Turntoo model:
 - The customer pays for performance only (a form of leasing / an performance based effect-oriented product service system)
 - The manufacturer retains ownership of products, as well as responsibility for them
 - Through this model, design-for-recycling and design-for-disassembly are to be rewarded and promoted
 - Value is to be retained through conservation of product structures (i.e. reuse, refurbishment and remanufacturing)
 - Same-value (and same quality level) recycling is require, low-cost recycling is desired
 - In general, decisions are driven by a desire for preserving material resources as well as capitalizing on the in the long-term

Topics/questions

- Company introduction
 - What does your company do, related to RL and CLSC?
 - What are your responsibilities?
 - Who are the company's customers?
 - What type(s) of products does the company handle?
- Drivers
 - What are the main drivers for engaging in RL and CLSC (for both company and customers)?
 - What role do RL and CLSC play in your company, its activities and its vision?
- Other actors
 - Who are main competitors and how do you differentiate from them?
 - Who do you collaborate with and why?
 - How do RL and CLSC affect customer relations?
- Implementation
 - Which structures/processes does your company have to successfully organize RL and CLSC?
 - o What makes RL different from conventional logistics?
 - How specific are the competencies your company has for the products it handles?
 - Which barriers do you encounter in your RL and CLSC activities? (e.g. laws & public policy, business & economy, socio-cultural and technology)
- Innovation and learning
 - Is there feedback from RL and CLSC activities to product design, and how is this organized?
 - o Does process innovation related to RL and CLSC take place?
 - What are the effects of product/process innovation?

Conclusion

- Is there anything you would like to add? E.g. issues that did come up during the interview but of which you think they are important to this research?
- We (Jasper and Jelle) expect to conclude our research in January and March, respectively and will be happy to send you copies of our reports
- Thank you very much for this interview and for your time

Interview protocol used when interviewing (academic and consultancy) experts Introduction

- Would you agree if we record this interview for purposes of this research?
- Introduction of the research goals, and the purpose of the interview
- Explain why we approached the interviewee
- Introduce Turntoo and the Turntoo model:
 - The customer pays for performance only (a form of leasing / an performance based effect-oriented product service system)
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 - In general, decisions are driven by a desire for preserving material resources as well as capitalizing on the in the long-term

Topics/questions

- Which characteristics should a CLSC have, when it is to support the Turntoo model?
- What are challenges and enabling factors for CLSC and the Turntoo model on a macro level?
 - o Laws & public policy
 - o Business & economy
 - o Socio-cultural
 - Technology
- What are challenges and enabling factors for CLSC and the Turntoo model on a firm level?
 - o Strategy
 - Customer relations
 - o Competition
 - o Partners & collaboration
- On a firm level, which structures and processes are required to realize CLSC?
 - o Existing structures and processes
 - Supply chains
 - o Innovation
- Which companies are (partial) frontrunners in various aspects of realizing CLSC? (e.g. RL, remanufacturing, recycling, reuse, remarketing)
- In which markets do we find frontrunners, and why there?

Conclusion

- Is there anything you would like to add? E.g. issues that did come up during the interview but of which you think they are important to this research?
- We (Jasper and Jelle) expect to conclude our research in January and March, respectively and will be happy to send you copies of our reports
- Thank you very much for this interview and for your time