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Understanding Closed-Loop Supply Chain Management: a Theoretical Discussion

Margarete Seitz

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Margarete Anna Seitz

Abstract

The increasing global awareness of environmental problems and the creation of a 'global agenda for change', The Brundtland Report (World Commission on Environment and Development, 1987), has affected industries worldwide. As a result, the awareness of product take-back and recovery activities has increased in various industry sectors but also attracted interest in academia. Reverse logistics and closed-loop supply chain management are just two examples of how environmental issues have been incorporated into an academic context. However, these areas of research may still be considered as fairly young. Hence, the lack of a distinct theoretical base for research in the area of closed-loop supply chain management has been considered as an issue by main contributors. This Working Paper aims to fill this gap by seeking to identify elements within existing theories that could explain observed phenomena in closed-loop supply chain research.

Firstly, the Working Paper demonstrates the lack of a theoretical grounding for this relatively new field. Secondly, it explains why it is essential to any type of research to be provided with a theoretical framework in which testable hypotheses can be embedded. It also outlines the characteristics of a theory. Several concepts and theories, such as sustainable development, industrial ecology and systems thinking are reviewed and assessed with regard to the contribution they could make within the development of a theory for closed-loop supply chain management. The findings summarise and outline the aspects each individual theory provides. However, more empirical research needs to investigate real-world closed-loop supply chains in order to completely understand this new field of research.

Keywords

Closed-Loop Supply Chain Management, Sustainable Development, Industrial Ecology, Systems Thinking

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Introduction

"Good theory is practical precisely because it advances knowledge in a scientific discipline, guides research toward crucial questions and enlightens the profession of management" (Van den Ven, 1989, p.486)

The term closed-loop supply chain has not appeared as such in the literature on supply chain and operations management until the beginning of this century. Several authors have spoken of 'reverse supply chains', a topic which was mainly discussed in practitioner circles (e.g. Cruz, 2000; Morrell, 2001; Serant, 2001). However, a clear definition of closed-loop supply chain only seems to have emerged thereafter. In their earlier work, Guide and Van Wassenhove (2000) discuss closed-loop supply chains for refillable containers, photocopier remanufacturing and the re-use of consumer electronics. Probably the first contributors in designing a closed-loop supply chain were Thierry *et al.* (1995) with their model of an 'integrated supply chain'. This chain of companies has been defined as a supply chain, which comprises service, product recovery, and waste management activities. Figure 1 shows their supply chain model. In this model, products return from the end-user to undergo a product recovery operation, such as re-use, repair, remanufacture or recycling. Thereafter, products are integrated back into the 'forward' supply chain.

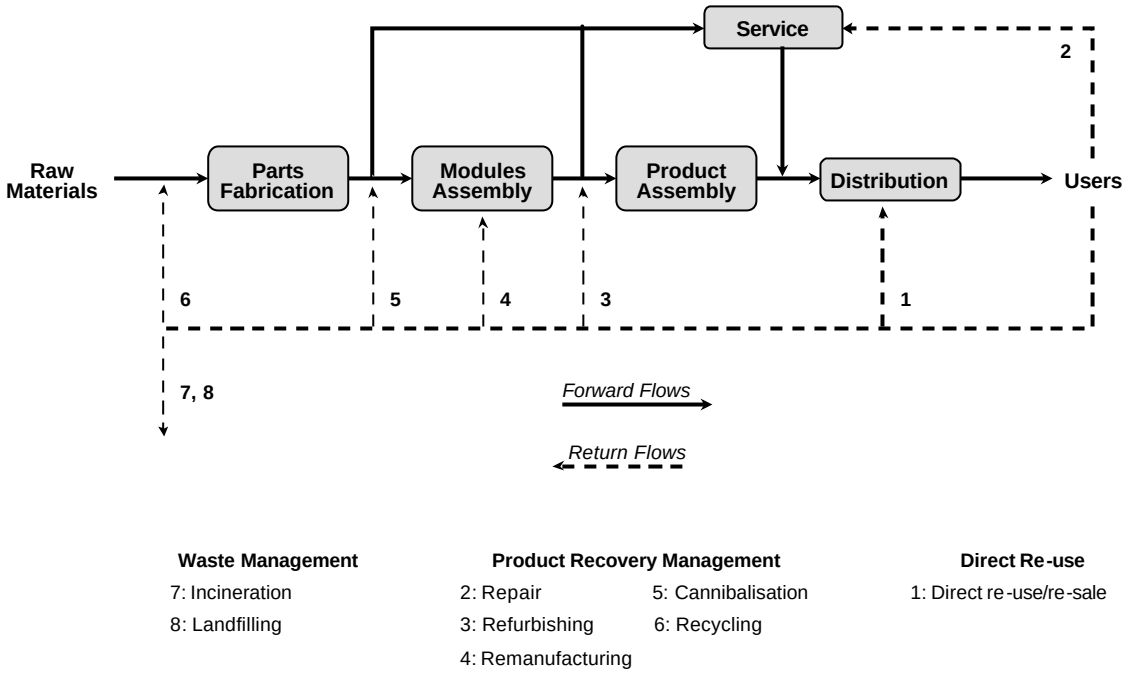

Figure 1: The Integrated Supply Chain (Thierry *et al*., 1995, p.118)

Closed-Loop Supply Chain Management includes processes and operations that can not be found in conventional supply chain management. Krikke *et al.* (2004) explain that a closed-loop supply chain consists of a forward and a reverse chain. Guide and Van Wassenhove (2003) further add that the additional activities the reverse supply chain includes comprise product acquisition, reverse logistics, test, sort, disposition, refurbish as well as distribution and marketing. While there are a variety of theoretical considerations for conventional supply chain management, there is still a lack of a theory for closed-loop supply chain management, particularly with regard to the additional elements that the reverse supply chain incorporates.

A theory is defined as

"[…] *a coherent set of general propositions, used as principles of explanation of the apparent relationships of certain observed phenomena"* (Zikmund, 1994, p.20).

In other words, a theory is a set of statements or claims with regard to a certain phenomenon (generic behaviour), which is seen as valid after being tested throughout a number of cases (Keating, 1995). While the field of closed-loop supply chain

management is becoming more and more mature, various researchers in the area have criticized the lack of a theoretical grounding (e.g. Handfield *et al.*, 1997; Carter and Ellram, 1998; Van Hoek, 1999; Dowlatshahi, 2000).

This Working Paper argues that based on a review of theories and concepts from related fields, such as sustainable development, systems thinking or industrial ecology may provide the first elements for what could later develop into a closed-loop supply chain management theory. Attempts at taking an interdisciplinary approach have been made by Geyer and Jackson (2004). However, the aim of this Working Paper is to exploit the combination of supply chain management and the environmental social sciences to create a theoretical foundation for closed-loop supply chain management research.

Problem definition

As opposed to research in other disciplines, within operations and supply chain management, theory-building has often taken a less prominent position on the research agenda (Amundson, 1998). Particularly the disciplines from the social sciences, have traditionally focused on the study of theory (see, for example, Glaser and Strauss, 1967; Charmaz, 1983; Strauss and Corbin, 1994). Closed-loop supply chain management, too, lags behind other disciplines with regard to theory-building. This fact is particularly true, since closed-loop supply chain management is only represented by a relatively short research history. The earliest contributions in the field were made on reverse logistics in the early 1990s (e.g. Pohlen and Farris, 1992; Stock, 1992). Publications on closed-loop supply chain management followed in the beginning of this century with leading articles by Guide and Van Wassenhove (2000, 2002, 2003). Various authors in the area of reverse logistics, product take-back and recovery have criticized the lack of a theory or the absence of a theoretical framework for research in this field.

"Because the academic research focus on these environmental issues is relatively new, little prior theory exists in which to ground testable hypotheses concerning the role of environmental management in the operations management value chain" (Handfield *et al.*, 1997, p.294).

However, the theory-building process is essential to distinguish scientific knowledge from common sense (Reynolds, 1971). Handfield and Melnyk (1998) further confirm

the importance of theory for any research and argue that empirical research becomes 'data dredging' without a theory. Consequently,

"[…] *data, whether qualitative or quantitative, characterize; theory supplies the explanation for the characteristics. Therefore, we must make sure that what is passing as good theory includes a plausible, cogent explanation for why we should expect certain relationships in our data"* (Whetten, 1989, p.491).

Van Hoek (1999) confirms the lack of a grounded theory for green supply chain management:

"[…] *literature on the role of supply chain operations, mostly published in the area of reversed logistics, has failed to develop grounded theory and frameworks to support the application of such an approach"* (p.129).

He therefore recommends two needs for research. First of all, future research has to go beyond the limited perspective of reverse logistics. Hence, a holistic view is required, which includes the entire (green) supply chain rather than reverse logistics only. Secondly, more work is required with regard to the development of a theoretical framework for research on green supply chains.

The research requirements outlined by Whetten (1989), Handfield *et al.* (1997) and Van Hoek (1999) have shaped this article. Its overall objective is therefore to review theories and concepts which may provide elements to the development of a grounded theoretical framework for closed-loop supply chain management. In order to explicitly illustrate these elements, all theories are reviewed with regard to the contribution they can make to the aspects of efficiency and effectiveness within closed-loop supply chain management. Efficiency and effectiveness have been identified as key concepts and important measures of performance by (Thompson, 1993).

Review of existing theories and concepts

There are contributors who argue that one of the main weaknesses within research is the belief that there is no appropriate theory. These contributors also criticize the alleged

lack of an appropriate theoretical framework is used as justification for the application of case study strategies. With regard to Operations Management (OM), Stuart et al. (2002), for example, state:

"*The rationale behind using cases as a research method in OM is no exception.* […] *a major weakness of OM researchers in this first stage is the presumption that applicable theory does not exist. Contributing theories may well exist outside OM's traditional boundary"* (p.423).

These authors therefore recommend a thorough assessment of theories in related fields, such as marketing, manufacturing or finance, which may result in the application of these theories or parts of the theories in other disciplines, such as operations management. This article therefore firstly reviews exiting theories, concepts and debates from the environmental social sciences, in order to evaluate whether these could be applied to closed-loop supply chain management.

The reasons for investigating theories and concepts from the environmental social sciences as opposed to theories from related business studies (as Stuart *et al.* have suggested), are justified as follows. Firstly, contributors in the area of closed-loop supply chain management and remanufacturing research have generally not sought to consult theories from the environmental social sciences. Theories which previous research has examined often narrowly focused on the recovery operation itself, rather than the whole closed-loop supply chain. Examples include inventory control theory (e.g. Van der Laan, 1997; Van der Laan *et al.*, 2003; De Brito and Dekker, 2003), contingency theory (e.g. Guide and Van Wassenhove, 2002) or repairable inventory theory (e.g. Schrady, 1967; Guide and Srivastava, 1997). Secondly, theories in supply chain management have always focused on efficiency with regard to the use of time, energy and finances and overall profitability. However, researchers who are concerned about environmental degradation may not aim to achieve profitability of a certain business or operation, but may share environmental values with academics from the social sciences. As a result, taking the viewpoints of social scientists adds another perspective to closed-loop supply chain management. Thirdly, the increase in product take-back and recovery regulations, as for example in Europe (e.g. CEC, 2000, 2002), seems to demand for a consultation of ideas from research fields related to environmental protection. As a result, the theories and concepts reviewed within this

Working Paper include sustainable development, industrial ecology and systems thinking.

Sustainable development

The sustainability approach seeks to combine the present industrial development with the requirements of future generations (Wilkinson *et al.*, 2001). In 1987, the Brundtland Commission defined the term 'sustainable development' as the development that

"meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p.43).

This definition comprises two ideas. Firstly, there is the notion of 'needs', which represents the essential needs of the poor. Secondly, there is the idea of 'economic limitations', so that future generations will be able to meet their own needs. However, sustainability implies a redistribution of wealth from current to future generations and from developed to developing nations. It also suggests the aggressive restriction of population growth (Allenby, 1999).

Concerns that future generations may not be able to meet their needs are not at all new. Early contributors, such as Thomas Malthus (1766-1834), discussed the effects of population growth and food supply (Robinson, 2002). Today, the concept of sustainable development shows more facets than simply securing food supply.[1] However, one of the problems is the breadth of the concept, which seeks to include a variety of areas and tries to accomplish a large diversity of objectives.

"Nevertheless, despite the diversity of interpretations, most supporters of sustainability agree that it involves a fundamental concern for the health of the physical environment, economic prosperity, and social wellbeing, and achieving a balance in these objectives over time" (Smith, 2002, p.14).

Hence, the concept of sustainability comprises four dimensions, the social, the economic, the environmental and the institutional dimension. The breadth of the concept

[1] Others argue that sustainable development may be seen as the all-embracing idea and umbrella of theories such as industrial ecology. Isenmann (2003) defines industrial ecology as the 'science of sustainability'. However, discussions with regard to the extent to which industrial ecology can meet these claims have followed Isenmann's statement (e.g. Ehrenfeld, 2004). Sustainability

complicates the operationalisation and achievement of individual goals or milestones. Graedel and Allenby (1998) illustrate that the vision of a 'sustainable development' is worthy and necessary, but ambiguous and too broad to operationalise. In their eyes it is therefore necessary to break this vision down into smaller concepts, such as industrial ecology. Hereby, industrial ecology is perceived as a multidisciplinary study of industrial and economic systems and their interrelations with natural systems (Graedel and Allenby, 1998).

Industrial ecology

The roots of what is nowadays known as industrial ecology began with reference to the term 'metabolism' and can be found in various other disciplines, such as biology, biochemistry or physiology. In the middle of the 19th century, the term metabolism was first applied to society (Fischer-Kowalski, 2002), while in the 1960s, the discussion was extended onto the modern industrial society, with Wolman (1965) and Ayres and Kneese (1969) making the first contributions. With regard to the contemporary industrial systems, Graedel and Allenby (1998) explain that the concept of industrial ecology deals with the interactions of society, industry and the environment. Industrial ecology is therefore defined as:

"[…] *the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimise the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital"* (Allenby, 1999, p.40).

As a result, industrial ecology may be described as the industrial perspective of sustainable development. The concept is embedded within the idea of sustainable development, but focuses on industrial action without denying or ignoring the importance of other subsystems of sustainability. As described in the above definition, industrial ecology investigates the total materials cycle from cradle to grave. However, unlike in the above definition, the aim of industrial ecology should be the recovery of

may be seen as the superior concept for theories in the environmental social sciences. But still, since the concept of sustainability has not been around long enough, problems of its definition occur (Smith, 2002).

any obsolete or end-of-life product (closing the loop), rather than its disposal. This is the main idea on which closed-loop supply chain management is based. Hence, if industries seek to close an endless, repetitive materials cycle, an extension of the above definition is necessary, as for example suggested by Frosch and Gallopoulus (1989). In other words, 'ultimate disposal' in the above definition should be replaced by 'the return of obsolete products for recovery'. Allenby (1999) adds:

"A critical element of industrial ecology, in fact, is to understand how economic systems can be evolved so that materials do not simply pass through the economy in a linear fashion and become waste […]*, but are cycled within the economy to the greatest practicable extent* […]*"* (p.133).

The central theme within the discipline of industrial ecology is the idea of taking ecology as a blueprint for designing sustainable business strategies, or the so-called 'eco-mimicry' (Anonymous, 2001). Bourg (2003) describes this phenomenon as taking the lessons from natural metabolism in order to artificially form an industrial metabolism. However, there is an ongoing debate among contributors, whether the natural ecology can be used as a template for conducting business. Bill Shireman, one of the main contributors in this field, explains why this idea can work.

"*Industrial ecologists define industrial ecology as the application of ecological principals to business, looking at business as a living system. We see business as a living system that is composed of people who are themselves living systems. Businesses are also communities; they adapt, they evolve, and they show those characteristics of living principles. So we say that if it works for nature, it can work for business"* (in Anonymous, 2001, p.19).

John Harte questions the key-point of taking nature as a blueprint for industrial action. In his eyes, natural ecosystems are too complex and cannot be applied to businesses. He argues that the environmental system is relatively unstable. Industry and economy, however, ask for stability. Instead of taking the insights of ecology as a blueprint or template for designing sustainable business, John Harte therefore suggests the second approach known to researchers in this area. It implies the thinking in terms of lessons systems can learn from the natural ecology. John Harte therefore concludes:

"*In summary, nature is hardly a template for how an industrial society should work. Applied to human society, what nature does is impractical for us to copy on a global scale, and wasteful, unstable, and sometimes even unethical for us to try to mimic on a local scale. However, nature does impose boundary conditions on our behaviour. We can ignore these constraints and live off of declining ecological capital for a while, but in the long term, we are going to have to adapt to nature's limits. If we don't adapt, we risk extinction – if not of our species, of our civilization"* (in Anonymous, 2001, p.19).

Systems thinking

General systems theory firstly emerged from the work by Köhler (1924) and was further developed by Von Bertalanffy (1968) and Boulding (1956), who suggested that an organization should be seen as a set of integrated components, each with a certain purpose. A system can therefore be understood as an accumulation of parts forming a unitary whole (Johnson *et al.*, 1973), or 'a set of interrelated elements' (Ackoff, 1971). In other words, the understanding of a system includes the wholeness, its formation out of elements and the interaction between those elements. With regard to supply chain management, systems thinking has influenced the discipline by 'thinking of the whole', rather than of individual aspects. This can be interpreted in two different ways. On the one hand, specific functional areas within one organization should not be seen in separation from the other functional areas in the same organization. On the other hand, it may be argued that a systems approach aims to understand the whole supply chain and the interaction of the supply chain echelons, rather than focusing on one organization only.

General systems theory, however, is not only concerned with how an organization operates, but it also seeks to investigate the interaction between an organization and its environment. A distinction can therefore be made between open and closed systems. Closed systems operate independently from the environment and without outside influence; open systems describe an interaction between the organization and the outside world (Hodge and Anthony, 1991). These definitions are based on the work by Köhler (1924, 1938), who observed systems that interacted with their environments and therefore called them 'open systems'.

Systems theory is relevant to closed-loop supply chain management for two reasons. Firstly, it shares common roots with industrial ecology theory. Boulding (1966), for

example, refers to the work by Von Bertalanffy (1952). Key contributors within industrial ecology, such as Allenby (1999), argue that the understanding of complex economic systems is an essential element of industrial ecology. In addition, industrial ecology applies tools that are similar to the methods used within research that takes a systems perspective (input-output models; systems modelling). The critical need for a systems perspective within industrial ecology is also emphasized by Lifset and Graedel (2002). In their eyes, systems thinking can be found within industrial ecology due to the life cycle perspective that is adopted and the material and energy flow analyses that are applied. Definitions of the term industrial ecology, such as by Allenby (1999), refer to a 'systems view', 'industrial systems' as well as 'surrounding systems' and the optimization of resources, energy or capital. Moreover, both theoretical perspectives incorporate elements of 'efficiency' and 'optimization', with regard to materials, capital, energy or processes, for example.

Discussion

Within this Working Paper, a theory was defined as a set of statements which is perceived as truthful with regard to certain phenomena (Zikmund, 1994; Keating, 1995). It was also pointed out that data characterize, but only theory supplies the explanation for these characteristics (Whetten, 1989). Due to the fact that the field of closed-loop supply chain management is relatively young and based on the observation that theory-building in this area has not been perceived as a major objective on the research agenda, the need to identify an appropriate theory for closed-loop supply chain management was expressed by various contributors. As a result, theories from the environmental social sciences were examined with regard to their suitability to provide explanations for observed phenomena in closed-loop supply chain management research. This section reviews, summarizes and discusses the specific characteristics of each theory.

In order to illustrate the individual elements each theory contributes to closed-loop supply chain management, a *Map of Sources* (see Figure 2 below) has been created. It takes two key concepts and measures of performance, efficiency and effectiveness, as guiding aspects for sorting the elements filtered from the theories. Within Figure 2, efficiency is understood as using resources, such as time and energy, well and with

minimum waste (Thompson, 1993). Efficiency within this article is two-dimensional, covering economic and environmental efficiency. Environmental efficiency hereby incorporates aspects such as waste reduction or resource efficiency, whereas economic efficiency targets costs. Effectiveness, which is defined as the successful achievement of results or goals (Thompson, 1993) comprises the dimensions of competitiveness and the 'fit' of the organization with its environment. Overall a corporation can achieve strategic effectiveness by

"taking into account the company, the competition and the industry as a whole" (Thompson, 1993),

but also by considering aspects such as corporate objectives, the competitive environment, the company's strengths and weaknesses as well as future changes in the environment. With regard to closed-loop supply chain management, one example for strategic effectiveness could be the pre-empting of future take-back and recovery legislation and hereby achieving a competitive advantage.

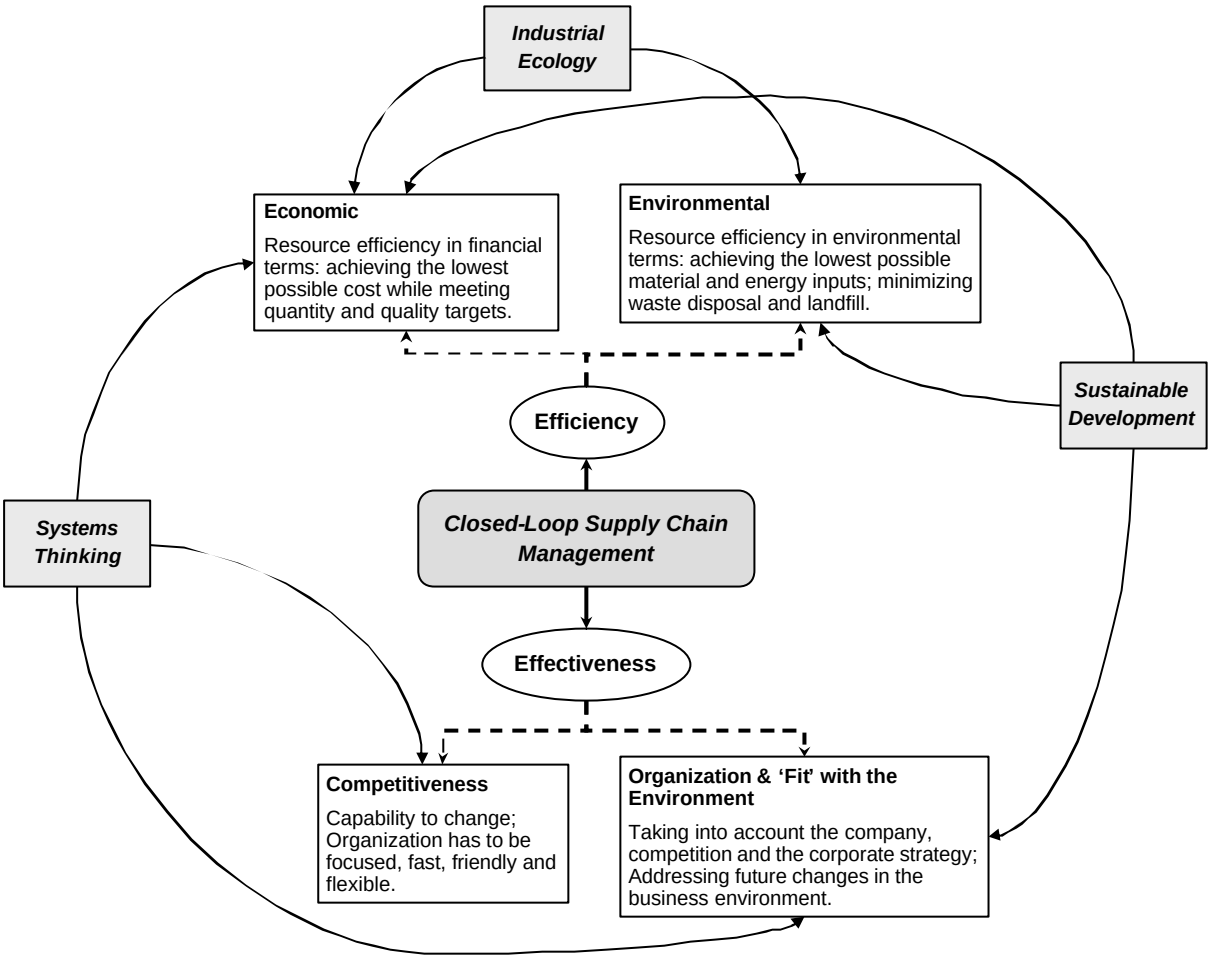

Figure 2: Map of Sources – Closed-Loop Supply Chain Management Theory (Explanations partially adopted from Thompson, 1993)

Contributions from sustainable development

Sustainable Development was identified as a far-reaching concept that aims at combining present industrial development with the requirements of future generations. It comprises four dimensions, the social, the economic, the environmental and the institutional dimension. As a result, sustainable development has an impact on closed-loop supply chain management in various ways.

Firstly, sustainable development affects our understanding of the environmental efficiency of closed-loop supply chain management (Figure 2). It demands that future generations are able to meet their own needs. In this way, commitment to sustainable development provides support for product take-back and recovery, which is a key

feature of closed-loop supply chain management. By re-using, recycling or remanufacturing used or worn-out products, less waste occurs and less resources are needed within the manufacturing process, which are therefore available for future generations. It also sets an example for future generations on how a sustainable economy can be achieved.

Secondly, sustainable development implies 'economic limitations' of current generations. A corporation can be economically more efficient by managing resources at the lowest possible cost, while achieving quantity and quality targets (Thompson, 1993). With regard to closed-loop supply chain management, the take-back and recovery of used products not only achieves environmental, but also economic goals, as less new materials have to be procured.

The third aspect that sustainable development adds to a theory for closed-loop supply chain management refers to the 'fit' between an organization and its environment. Sustainable development also means to balance the needs of different stakeholders, but also comprises 'futurity' as the needs of future generations. With regard to closed-loop supply chain management, the theory explains why it is essential for all supply chain echelons to work together. Balancing the interests of all supply chain members and stakeholders supports the focus on long-term objectives in order to ensure the survival of the supply chain as whole.

Contributions from industrial ecology

Industrial Ecology has been defined as the 'science of sustainability'. It is characterized by applying metabolic thinking onto industrial systems. Overall, industrial ecology aims at the optimization of the total materials cycles. Factors that can be optimized include resources, energy and capital. Industrial Ecology therefore provides elements to the environmental and economic dimensions of efficiency in Figure 2.

In order to achieve environmental and economic efficiency, industrial ecology theory provides a set of tools to measure product and material flows. These tools include life cycle analysis, material flow analysis and physical input-output accounting (see Ayres

and Ayres, 2002). Previous researchers, such as Linton *et al.* (2002) and Geyer and Jackson (2004) have applied these tools to identify issues in remanufacturing, recycling and reuse, respectively. Publications, such as by Allen (2002), show a very specific material flow analysis of waste as raw-material. The compilation and analysis of material flows may seem very much focused on the chemical composition, however, such tools and knowledge may inform closed-loop supply chain and product recovery management in various ways. On the one hand, from a supply chain perspective, it may be measured whether product take-back processes (reverse logistics; transportation) are more harmful than landfill (in environmental terms). On the other hand, a detailed material flow analysis may be produced for any recovery processes. Such analyses demonstrate the environmental impacts of remanufacturing or recycling, for example. Smith and Keoleian (2004), for example, have undertaken a life-cycle assessment model for remanufacturing, taking the case of car engines. Research of this type may complement and extend research that takes a logistics or supply chain management perspective (e.g. Seitz and Peattie, 2004). Input and output measurements could also help to discover inefficiencies within the recovery process. Overall, the tools and techniques applied within industrial ecology research are therefore beneficial for measuring efficiency within closed-loop supply chains.

However, industrial ecology theory provides further ideas to the generic understanding of closed-loop supply chains. Industrial ecology theory has presented a framework for the relationships and causalities within closed-loop supply chain management in the idea of the endless, repetitive materials cycle, or the 'industrial metabolism'. There are examples of closed-loop supply chain models in which this idea is pictured (e.g. Thierry *et al.*, 1995; Guide *et al.*, 1999; Majumder and Groenevelt, 2001; Meade and Sarkis, 2002; Mahadevan *et al.*, 2003). In addition, academic contributions within the field of industrial ecology inform closed-loop supply chain management research. A good case in point is the work by Graedel *et al.* (2002), who picture the complete life cycle of an automotive vehicle from raw material extraction to end-of-life. This material flow perspective, which is often applied within industrial ecology research, assists with the correct identification of material and product flows within closed-loop supply chains, rather than providing idealized conceptual models which are difficult to apply onto real-world situations. Closed-loop supply chain management has traditionally focused on the

product flows along the supply chain, the actual recovery processes, as well as the relationships between companies involved in the management of the chain. In this way, industrial ecology thinking and closed-loop supply chain management may complement each other. Closed-loop supply chain management provides a whole account of the supply chain, whereas industrial ecology focuses on the detailed description of material flows and their potential optimization.

Contributions from systems thinking

Systems thinking, which provides a sound theoretical basis for traditional supply chain management contributes several new elements to the theory for closed-loop supply chains. The economic-technical branch of systems theory has traditionally focused on maximizing (economic) efficiency (Kast and Rosenzweig, 1981). By using resources more efficiently, the competitiveness of a supply chain is increased, too. However, there are further factors with which systems thinking can enrich closed-loop supply chain management.

Traditional systems thinking can still be successfully applied to the forward supply chain. For the reverse supply chain, it offers a second dimension. One example is the concept of 'holism'. The systems approach assists in the understanding of the closed-loop supply chain as a system, its composition of individual elements (companies; supply chain echelons) and the interaction between these elements. This also means considering the interplay between forward and reverse chain. As an example, considering reusability in the product design (e.g. 'design for environment', 'design for remanufacturing') in the forward supply chain, will have beneficial impacts on the reverse chain (e.g. easier product disassembly; reduced disassembly times). With regard to academic research, systems thinking also directs research in the right direction: the aim is to investigate the closed-loop supply chain as a whole, rather than focusing on individual elements of the chains.

Moreover, systems thinking provides the definitions for open and closed systems, an aspect which has only been marginally investigated by previous research in the field, such as by Fleischman *et al.* (2000). As the term closed-loop supply chain suggests, the

emphasis is put on a closed system. The idea of endless, repetitive material or product cycles has been borrowed from industrial ecology theory, but the definitions for open and closed systems can be taken from systems theory. While some contributors argue that a closed-loop system requires that there are

"[…] *no virgin materials added and everything is recycled and re-used"* (Wells and Nieuwenhuis, 2001, p.37),

it is still questionable whether such a closed-loop system can be achieved in cases where products have left the factory gates.

Conclusions

Figure 2 has summarized the specific aspects in which existing theories can contribute to the understanding of closed-loop supply chain management. However, it has become clear that even though existing theories contribute different aspects there are still gaps. This particularly refers to the lack of understanding and explanation of specific characteristics within product take-back and recovery, such as the identification of the reasoning (motivations) behind those activities. While industrial ecology literature suggests the optimization of the total materials cycle, resources, energy, capital are drivers for the 'maintaining of a carrying capacity', Seitz and Peattie (2004) argue that rather market-related aspects, such as the supply of spare and replacement parts are reasons for product remanufacturing, for example. The ideas behind corporate social responsibility suggest that a company's involvement in corporate greening (e.g. product recovery) is driven by moral or ethical responsibility. Toffel (2004) was one of the first contributors who specifically investigated the motives for voluntary product recovery. While he still maintains the 'classic' motives of product recovery (reduction of production costs; promoting an image of environmental responsibility), he has also discovered novel motives, such as meeting customer demand, protecting the aftermarket and pre-empting regulation.

It is therefore concluded that different theories contribute the first steps to the basic structure of a theory for closed-loop supply chain management. However, there is still

the need to combine those elements into a coherent theory for the field. At this stage, closed-loop supply chain management is too underdeveloped to be completely understood, even by experts. As a result, there is the need for further empirical, in-depth research which investigates specific real-world closed-loop supply chains in order to understand aspects, such as the motivations behind the corporations' engagement in recovery activities, obstacles that could occur within closed-loop supply chains or strategies on how a closed-loop supply chain can be efficiently managed. These aspects and issues provide scope for an exchange of ideas between researchers from the fields of (closed-loop) supply chain management and the social sciences. In addition, more empirical research will provide further elements to the development of a theory for closed-loop supply chains.

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