Environmental Supply Chain Management: using Life Cycle Assessment to structure supply chains.

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Abstract

Recently more attention is given to Environmental Supply Chain Management (ESCM). One of the supporting instruments of ESCM is Life Cycle Assessment (LCA). The idea of integrating LCA into supply chains is gaining more support among research institutes and companies. However, we conclude that there are no guidelines for this integration. In this paper we argue that in line with a differentiation in environmental care chain strategies and in environmental chain performances, a differentiation in types of LCA's should be made; the compliance-, process- and market-oriented LCA. To execute these different types of LCA, the chain structure should be attuned to meet the specific requirements of these types. In an overview we will show that the integration of the types of LCA in a chain, bring along different chain structures.

1. Introduction

One of the most significant paradigm shifts of modern business management is that individual businesses no longer compete as solely autonomous entities, but rather as supply chains (Christopher, 1998). Strictly speaking, the supply chain is not a chain of businesses with one-to-one, business-to-business relationships, but a network of multiple businesses and relationships. Executives are becoming aware that the successful co-ordination, integration and management of key business processes across members of the supply chain will determine the ultimate success of the single enterprise (Van der Vorst, 2000). The need for successful linkages holds true especially in food supply chains because of the shelf life constraints of food products and increased consumer attention for safe and environment- and animal-friendly production methods (Boehlje et al., 1995). One only needs to refer to problems concerning BSE, foot-and-mouth decease and swine fever in Europe to picture the numerous interrelationships of actors in these networks. Lambert and Cooper (2000) underline this growing awareness of executives in their research agenda for Supply Chain Management (SCM). According to them a top priority in SCM should be research to develop a normative model that can guide managers in their efforts to develop and manage their supply chains.

Recently, more attention is given to Environmental Supply Chain Management (ESCM) defined as "the set of supply chain management policies held, actions taken, and relationships formed in response to concerns related to the natural environment with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services" (Zsidisin and Siferd, 2001). Life cycle assessment (LCA) can be seen as the main instrument of ESCM; it is a technique for gathering data on environmental care issues which can be used to restructure supply chains in order to improve the environmental performance of those supply chains. In general LCA is well described in the steps that are to be taken.

However when one develops a LCA from different perspectives and with different goals, different results are obtained; LCA is therefore a context dependent tool.

Furthermore, the fulfilment of environmental objectives by applying LCA requires specific ways of working and co-operation in the supply chain. Organisations can strive for different ambition levels of environmental care. We argue that when other levels are striven for, different supply chain structures are more appropriate.

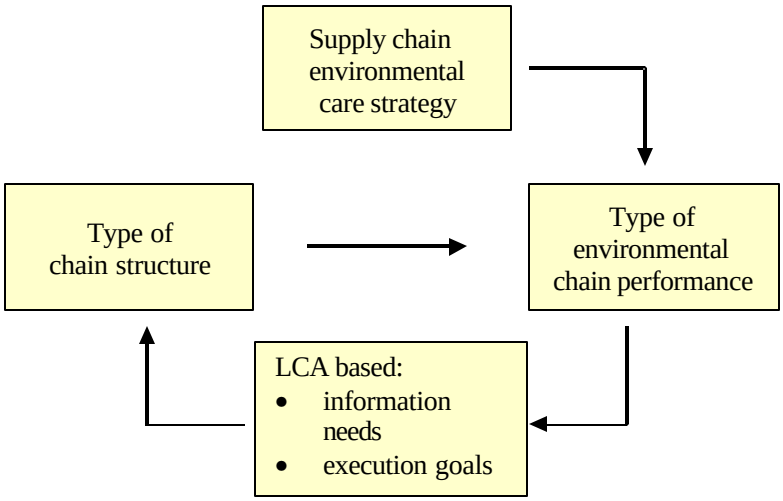

Figure 1. Research model

Figure 1 depicts our line of thought. Actors within a supply chain pursue a certain environmental care strategy; when all actors agree on that strategy one can state that there is a 'supply chain environmental care strategy'. This strategy is operationalised into a number of environmental performance indicators. When different strategies are pursued, different performance indicators emerge and/or different weighting is given to each indicator. Therefore, we can discern different types of environmental performances.

When a supply chain strives after realising specific performance objectives, one specific supply chain structure is more suitable than the other. Actors within the supply chain require information concerning emissions, products and processes to control, manage and steer the chain in the direction of its goals.

LCA provides information to measure the environmental supply chain performance; however, not all information is suitable in all situations. Certain parts of the LCA are more suitable when certain environmental objectives are pursued than other parts. This leads us to the following problem statement:

1. What (selection of the) LCA data is required when a certain environmental care strategy is adhered to (so how should LCA be used)?
2. What types of environmental performance objectives can be distinguished?
3. What supply chain structure is (most) appropriate for realising those objectives?

By answering these research questions, we hope to contribute to theory and practice on the following aspects:

- to develop guidelines for managers in their efforts to develop supply chains from an environmental perspective;
- to relate the environmental supply chain to its environmental performance; and,
- to assess the applicability of LCA as a tool for SCM.

In the following sections we will elaborate on the terms used. Section 2 discusses supply chain management and partnership. Section 3 focuses on LCA. Environmental care strategies leading to types of LCA are the subject of section 4. Next, we will discuss requirements to supply chain structures (supply chain co-operation in particular) in order to implement the different types of LCA. Section 5 will present four types of supply chain structures and, finally, section 6 will present the conclusions.

2. Supply chain management

Over the years several definitions have been developed that describe chain co-operation. At this stage there seems to be no single universally accepted definition which generally covers the field of interest. The following descriptions have come out of the debate (Migchels, 2001):

- "organisations that commit themselves, based on expectations of consumers, stakeholders and physical dependencies" (Beers et.al., 1998);
- "by focusing on consumer needs a temporary and partial network will develop of common activities and exchange of people, resources and information" (Zuurbier et.al., 1996);
- "the integration of business processes from consumer to the original suppliers leads to product-service-information that has added value to customers (Cooper et.al., 1997).

These definitions may differ in many respects as they are designed to limit a particular field of research or to fit a specific situation. However, commonalties can still be found. Key words that are used in many of the definitions of chain co-operation are (Migchels, 2001): a network of several organisations; processes and transactions; achieve better results; control and co-ordination; vertically organised; consumer oriented; flexible, non-integrated organisation.

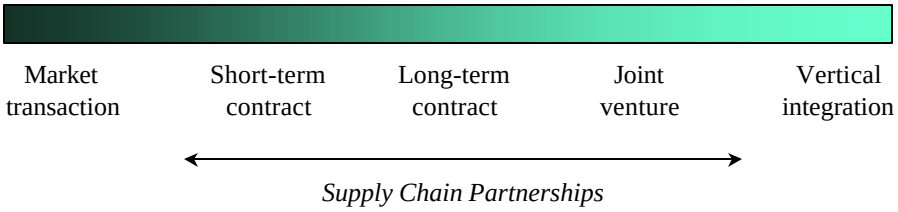

Figure 2 Typology of supply chain partnerships

Within the supply chain, relationships may take on a variety of legal forms, including vertical integration, long-term contracts, and market transactions. Cooper and Ellram (1993) view SCM as lying between fully vertically, integrated systems and those in which each channel member operates completely independently (Figure 2).

In strategic partnerships the emphasis is on co-operation and partnership between the parties, not competition and conflict, as the basis upon which a joint competitive advantage is developed. Partnership refers to a relationship that attempts to build interdependence, enhance co-ordination, improve market position focus (by broadening or deepening), or to achieve other shared goals; and that entails sharing benefits and burdens over some agreed time horizon (Cooper and Gardner, 1993). Partnership is a tailored business relationship featuring mutual trust, openness, and shared risk and reward that yields strategic competitive advantage (Handsfield and Nichols, 1999). The application of LCA requires data transparency and policy congruence in the supply chain, and therefore openness and trust.

Table 1 combines the findings of literature on partnerships in marketing, contract law, economics and logistics (Cooper and Gardner, 1993; Zuurbier et al., 1996; Simpson and Long, 1998; and Lambert et al., 1998); it provides an overview of aspects mentioned in literature that are relevant in determining if a partnership is appropriate. Because each relationship has its own set of motivating factors driving its development as well as its own unique operating environment, the duration, breadth, strength and closeness of the partnership will vary from case to case and from time to time.

Table 1 Critical Success Factors for partnerships

Drivers for partnerships	Main partnership facilitators	Successful partnership characteristics
• Asset-cost efficiencies (cost reduction) • Customer service (e.g. shorter cycle times) • Marketing advantage (e.g. entrance into new markets) • Profit stability/growth	• Strategic complementarity • Corporate compatibility (culture and business goals) • Compatibility of managerial philosophy and techniques • Mutuality (joint objectives, share sensitive information) • Symmetry in power	• Joint planning • Global SC operating controls • Systematic operational information exchange (rapid and accurate transfer) • Sharing of benefits / burdens • Trust and commitment • Extendedness (the relationship will continue into the future) • Corporate culture bridge-building.

We conclude from this short overview of SCM-literature that there is a variation in motivations, facilitators and success characteristics to develop and maintain supply chains. This differentiation in partnerships must be incorporated in the fine tuning between the execution of LCA and the supply chain structure.

3. Life Cycle Assessment

In this paper, LCA is seen as a tool to structure and manage supply chains. ESCM presupposes information about all production stages of the product life in order to be more effective from a environmental perspective. LCA takes the chain into account from an environmental angle: from raw material to the use, re-use of and the disposal-stage of the product. The idea of integrating LCA into supply chains is gaining more and more support among research institutes and industry (Lefebvre, 2000).

Life Cycle Assessment is an instrument with which the environmental-effects during the life cycle of a product can be integrally assessed. Integral means that all the

processes which contribute to the environmental burden are incorporated in the assessment. Unfortunately, there is no standard way of executing a LCA; there are lots of definitions of LCA (Van Koppen, 2000). The definition of LCA with the most authority nowadays is the ISO 14040 definition (ISO 14040, 1997). In this ISO "code of practice" the LCA is divided into four main steps, i.e.:

- Goal definition and determining the scope
  In this section the questions which have to be answered by the LCA, are dealt with. The goal (for example, benchmarking of comparable products or identifying the contribution of different process steps) and the scope (the level of detail of information) are determined. An important step is the demarcation of the functional unit: the unit which is subject for the analyses of the environmental burden.
- Inventory analysis
  All processes that contribute to the environmental burden are inventorised. For each process the emissions, the mining of raw materials, the input of other products and the output of economic products are mapped and registered into an environmental data sheet.
- Impact assessment
  In this phase, the impact of the environmental measures (e.g. the emissions) on the environment are estimated by linking the environmental measure with environmental themes such as global warming, ozone depletion or nutrification.
- Interpretation
  The results of the inventory and impact assessment are interpreted by the researchers from the perspective of the goal and scope definition.

In literature we can find quit a few problems and ambiguous moments of choice in the execution of LCA's (Bras-Klapwijk, 1999):

- Representativity and ligitimacy
  The question arises whether or not the LCA method results in a realistic reflection of the sustainability of chains. Missing data, calculation errors and disputable assumptions in the demarcation of the functional unit as well as in the choices underlying the participation of environmental themes and the weighing of those themes, can cloud a clear view on the environmental aspect of a chain. Considering these disturbing factors one can conclude that an LCA does not provide the absolute values (Van der Kolk, 1995).
- Specific usefulness
  Fraanje and Lindeijer (1993) state that the quality and usefulness of LCA leave a lot to be desired for because of missing and/or obsolete data, disputable assumptions, the lack of important alternatives and a poor aggregation of data. The lack of an environmental theme can be a problem when we want to reach a global representative result, but in the case of companies who want to optimize their environmental performance it should not be a problem. In the case of specific company or chain goals the problem can lie in the fact that LCA-databases are filled with average industry data. On the bases of such a global data-set it is difficult to choose a specific supplier for a specific company.
- Return
  Schaltegger (1996) stats that the current application of LCA is low on cost-efficiency. The gathering of data for specific chains is very expensive. On the

other hand, databases filled with average industry data can easily lead to wrong management choices in specific companies and chains.

- Comprehension en transparency
  The more complex the LCA, the less transparent and comprehensive it is for not environmental experts. The incomprehension can lead to two kinds of communicative problems: between the environmental staff and the general manager (see Schuster, 1998) and between the company and the consumer. Transparency depicts the level in which other parties have an inward view on the companies' processes. This view can be at odds with the confidentiality of the data in relation to the competitive position.

From a managerial perspective, we can conclude that the application of the LCA instrument is not without problems. Choices have to be made about the amount of resources one intends to invest in the execution of a LCA, about the required information to make far-reaching decisions including implementation, about the required information to satisfy stakeholders and, finally, about the publishability of information. These are all questions that have to be answered in order to be able to use the LCA-instrument in the company or the chain. It demands for a strategic choice in relation to the application of LCA. Strategic because there has to be a trade-off between the process lay-out, the co-operation intensity with suppliers and buyers, and the relation with the customers and other stakeholders.

4. Environmental care strategies and types of LCA

A literature research resulted in the following typology of environmental care strategies applicable to individual companies and supply chains (e.g. Vermaak, 1995, Spliethoff et al, 1991, Van Koppen en Hagelaar, 1998):

- Compliance-oriented: comply to rules and regulations with the help of end-of-pipe techniques;
- Process-oriented: strive for control of the environmental burden caused by the production process by means of production integrated measures in order to comply to governmental rules and regulations and to benefit their own return ('pollution prevention pays');
- Market-oriented: aim for the reduction of the environmental burden caused by the design of the product to achieve competitive advantage.

What ever the environmental care strategy is, companies should have insight in the following aspects:

- Environmental effects caused by the operational management, such as emissions of processes up to raw materials;
- Possibilities and constraints to influence the risks;
- The accountability on the bases of governmental rules and regulations;
- The already implemented technology;
- The market;
- The available budget.

In a supply chain strategic choices are made about environmental goals. This implicates that whenever the goals vary, the information needed to take decisions will vary as well. The goal functions as a selection criteria for the LCA-data needed. Based on this assumption we want to differentiate between the following types of LCA:

Table 2: Types of LCA

Type of LCA	Dataset
Compliance-oriented LCA	End of pipe (emissions etc.)
Process-oriented LCA	End of pipe, process steps, transport
Market-oriented LCA	End of pipe, process steps, transport, nature and quantity of raw materials, disposal.

When the environmental care strategy becomes more ambitious, the LCA has to generate more detailed information. We can see the direction of the information gathering going from the outskirts of the organisation (compliance), into the factory (process) and, finally, into the product (market). To be able to gather such detailed information in a reliable and efficient way, demands are put on the co-operation of the companies involved in the supply chain.

4. Requirements to types of LCA implementation

Multiple decisions concerning the scope of measures that reduce the environmental burden are possible. The LCA can trigger individual companies to implement such measures; it can also result in a joint effort in a specific place in the supply chain; it can even result in a joint decision for a changed product design (see Van Sonsbeek, 1997). It is clear that in order to make such joint decisions, some form of chain co-operation is required.

A chain is organised according to the collective targets of the participating companies and the conditions they agreed upon (Zuurbier and Hagelaar, 2000). We should be aware of the fact that, as we talk about multi-actor supply chains, not all chains are identical; external and internal demands to chains can differ and in this environment chains are designed. In order to typify a supply chain, we will distinguish three inter-related components of a supply chain that are specifically designed to meet those internal and external demands: institution, process and performance (see Trienekens, 1999; Mintzberg, 1983). *Institution* refers to the companies in the supply chains and the relations between them. The concept *process* depicts the sequence of activities of the parties involved. Finally, *performance* refers to the common objective of the chain (Trienekens, 1999).

The performance in this paper refers to the aimed environmental performance. It is defined as the result of the combination of the physical processes in the supply chain and the organisation which controls, manages and steers these physical processes. To fulfil the environmental performance objectives, the process and organisation should be designed in a specific way. Therefore, continuing our line of thought, each type of LCA requires its own type of process and institution to fulfil its specific performance objectives (Table 2).

Table 3. Requirements to types of LCA implementation

		Types of LCA	
Components SC	*Compliance oriented*	*Process oriented*	*Market oriented*
Institution	Fragmented	Negotation	Communal
Process	Black box: Identification of outside effects (emissions etc.)	Nucleus: Identification of internal effects and causes	Sublimation: Identification of contributions to the meta-result of the process
Performance	Addition of separate end-of-pipe performances	Addition of performances of end-of-pipe and of process steps	Integral, combined performance of end-of-pipe and of process steps, and disposal

We will discuss the two opposite types of LCA. The *compliance-oriented type of LCA* is directed towards the individual links in the chain. Every specific party in the chain has to comply to rules and regulations which define a basic norm which should not be passed. The process is in this type of LCA not of importance; it stays a black box because the attention is directed towards emissions etc.. The chain is a fragmented organisation since each company should individually comply to the, at specific companies directed (governmental) demands. The chain environmental performance in the compliance case is the addition of all individual performances.

The *market-oriented type of LCA* is the mirror image of the latter. The environmental performance is the result of the joint effort to design and produce a product. This requires a chain structure designed to work intensively together in order to open new markets. Integral and communal are key words. The ultimate result of the, in this kind of chain structure, well co-ordinated process steps is the integral level of analysis.

We can conclude that as the ambition level for the use of LCA increases, the chain requirements increase too in order to fulfil the higher environmental performance objectives. The final step in our research model is to differentiate supply chain structures to match with the three types of LCA.

5. Supply chain structures and requirements

We distinguish between four supply chain structures based on two dimensions (Figure 3):

- The extent of *complexity* of the supply chain, as defined by the number of functions (logistics, marketing, etc.) that are included in the partnerships;
- The *differentiation* of the structural linkage between the partners in the supply chain, defined as the number of consult structures between partners which influence the decision making process.

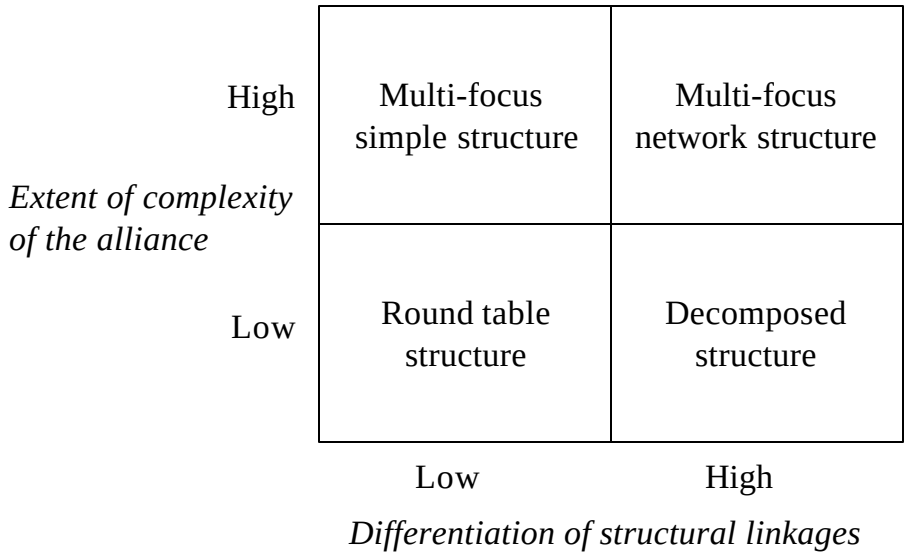

Figure 3. Typology of supply chain structures

The *round-table structure* is the most simple one. There are a few consult structures between partners influencing the decision making processes focused on one function to be fulfilled. All the other business functions and management functions are dealt with by each individual partner.

The *multi-focus simple structure* suggests that few consult structures between partners participate jointly in the decision making processes on several functions. Within each firm, the decision making is attuned to the joint decision making. This situation is very close to the hierarchical structure, where departments have small decision areas.

The *decomposed structure* is characterised by just a limited number of functions to be included in the partnership. However, the nature of those functions require a highly differentiated consult structure of co-ordination and fine tuning among the partners, horizontally and vertically. This situation occurs for example in highly technological advanced alliances.

The last structure, the *multi-focus network structure*, fits situations where the partnership deals with many functions and the decision making process is highly differentiated both vertically and horizontally. Mechanisms that are installed in these structures comprise: joint teams for individual functions, shared facilities, inter-functional and cross-functional interfaces, steering mechanisms for overall managing the alliance or supply chain, centralised and decentralised decision-making based on decomposition of problems (see Zuurbier and Hagelaar, 2000).

This description of chain structures shows that as complexity and consult structures increase, tighter partnerships are required. The multi-focus network structure puts high demands on the co-operation of supply chain partners. Of course, this is logical since more information is exchanged on processes and products requiring an ever-more open and trustworthy co-operation model. It can even be the case in this form of co-operation that companies invest in other companies to improve the overall environmental performance, following the Supply Chain Management line of thought. When we link these thoughts to the different types of LCA, we find the overview depicted in Figure 4.

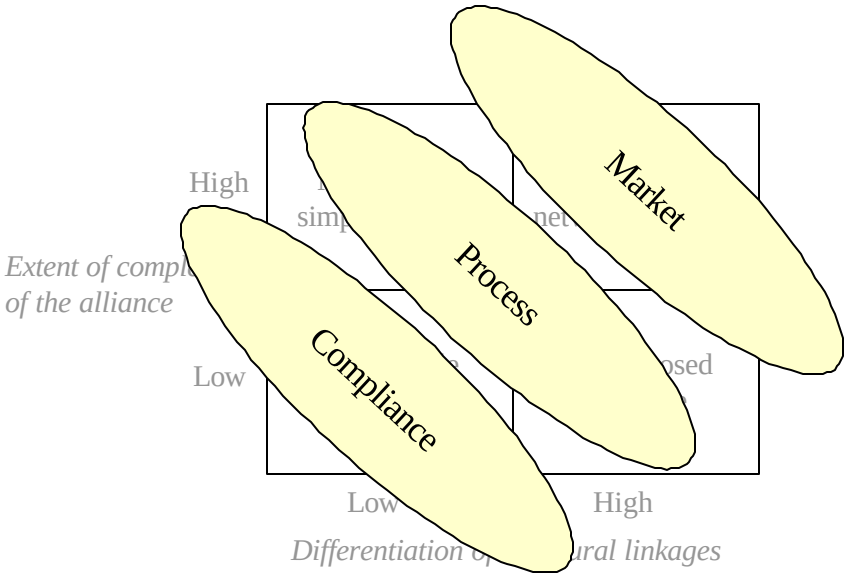

Figure 4. Chain structures and types of LCA.

6. Conclusion

In this paper we stressed three primary points to understand and guide the integration of LCA in supply chains. First, knowing about the environmental care strategy of the chain is an important first step to choose the type of LCA. This is critical for the managerial selection of information used in the LCA. Second, knowing the requirements to execute the LCA in the supply chain is critical to the feasibility of the execution of the LCA itself and of the results of the LCA. The managerial question crops up whether or not the planned environmental goals can be realised. Third, knowing the relation between the type of LCA and the type of chain structure is of importance for the assurance of the execution of LCA and the implementation of the LCA based goals of the environmental chain strategy.

We draw the conclusion that if chains want to use LCA as a management instrument, they may have to adjust the chain structure to meet the requirements set for the use of that instrument. When the suitable chain structure is not realised, the results of the information gathering as well as the implementation of the LCA based measures to reduce the environmental burden, will not be successful.

Finally, we want to claim that the relation between the type of LCA and chain structure is not static. After all, the choice of the type of LCA is conditioned by the choice of the environmental chain strategy. This strategy is influenced by factors outside the chain such as competition, governmental laws, consumer preferences and preferences of other stakeholders. The strategy is also influenced by chain-internal factors such as budget, knowledge, technology, co-operation etc.. In short, other, also more general analysis and choices have to be made which affect directly the choices concerning the environmental aspect of the supply chain. The integration of environmental care into the more general policy of chains should therefor boost the integration of LCA in supply chains.

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