Business Strategy and the Environment
Bus. Strat. Env. **13**, 306–319 (2004)
Published online in Wiley InterScience (www.interscience.wiley.com). **DOI**: 10.1002/bse.418

INDUSTRIAL ECOLOGY, LIFE CYCLES, SUPPLY CHAINS: DIFFERENCES AND INTERRELATIONS

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Within recent years, various concepts have arisen in environmental management that directly address the flow of material (and information) along life cycles or supply chains and thereby relate to inter-organizational management aspects. These include industrial ecology (IE), life-cycle management, closed-loop supply chains, integrated chain management and green/environmental or sustainable supply chain management. It is not clear how these concepts relate to each other and whether or how they are different. Starting with sustainable development three criteria are identified that allow the comparison of the four concepts. Building on definitions the concepts are discussed and analysed using the three criteria while also identifying a distinctive feature of each approach. The criteria reveal that the concepts take a specific approach to study material flows in their particular system boundaries. This also relates to the time frame usually applied within the concept as well as the relevant actor network taken into account. Beyond these differences, it arises that the concepts have their strengths on different levels, which leads to a framework for the interrelation of the concepts. Copyright © 2004 John Wiley & Sons, Ltd and ERP Environment.

Received 18 August 2003
Revised 21 January 2004
Accepted 5 February 2004

INTRODUCTION

The overall vision of sustainable development is widely supported, and much is done to transform it into business practice. A range of approaches claim to support this. This has been expressed prominently for e.g. industrial ecology (IE) by Ashford and Côté (1997), who characterize IE as 'a new unifying principle for operationalising sustainable development' and Allenby (1999a), who labels IE as the 'science of sustainability'. In a similar

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manner, 'life-cycle management (LCM) is called a business-driven approach including environmental and economic aspects' (Hunkeler *et al*., 2003), closely connected to sustainable development, and also allowing its operationalization. For supply chain management, there are first contributions that integrate environmental and social issues, such as related standards, thereby also aiming at sustainability (Seuring and Goldbach, 2004). This list might be continued for other concepts, while in addition to the two mentioned already only integrated chain management (ICM) and environmental/green/sustainable supply chain management (ESCM) will be taken up.

All of these are rather young fields of development. With all fields of science, it is important to reflect on their content (Easterby-Smith *et al*., 2002; for environmental-management-related examples see Newton and Harte, 1997; Isenmann, 2003). This has only been partly done so far and in an isolated manner where the various concepts are not integrated. Furthermore, to delimit the debate, it will be based on a managerial approach, i.e. it will not disregard the importance of technical aspects or other approaches within the mentioned concepts.

This paper aims to analyse and compare the four concepts, point out some differences and assess their interrelation. First, based on some reflections on sustainable development and a brief review of related research criteria for the analysis and comparison, the four concepts will be presented, which are the material flows and related system boundaries, the time domain and the actor network addressed. Next, the selected definitions of IE, life-cycle management (LCM), integrated chain management (ICM) and supply chain management (SCM) are presented and the criteria for analysis are applied to the individual concept. The next section proposes a framework that relates the concepts to each other, which builds on distinctive features of the concepts found in the analysis.

THEORIZING TOWARDS SUSTAINABLE DEVELOPMENT

'Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987, p. 43). The definition has triggered a new debate, where it is perceived as an overall approach requiring not only significant reduction of environmental burdens, but demanding 'much more systematic thinking and interdisciplinary approaches' (Welford, 1998, p. 6) and asking for the development of new theoretical foundations (Welford, 1998; Dobers *et al*., 2000). This is combined with the heuristic strength of sustainability, which offers a strategic action framework for companies (Matten and Wagner, 1998), but is not limited to an application in corporate strategies (Dyllick and Hockerts, 2002). This might explain why all four fields (which emerged in practice and applied research) have acquired some kind of foothold in existing theories, which allows steps to be taken towards theory building (Sutton and Staw, 1995; Weick, 1995). Still, the definitions presented below are taken as (non-generalizable) representatives of the field and show significant deviations. Meanwhile, there are some important papers that prepare the ground for wider theoretical work and relate to the scientific basis of the concepts.

Furthermore, some of the lines and relations between these concepts have been addressed, e.g. those between IE and LCA by Ehrenfeld (2003), who asks whether they are 'chicken' or 'egg'. A detailed comparison of ICM and (E)SCM is offered by Seuring (2004), who points out the different origins of the concepts. A basic conceptual integration of all of these fields has been proposed by Pesonen (2001, p. 46), but this does not really point out the differences among them. A large number of case studies have been presented in all areas (for two rather random examples, see articles by Korhonen (2002) and Seuring (2001)).

SELECTING CRITERIA FOR ANALYSIS AND COMPARISON

The question arises of how the four concepts can be compared, and according to what criteria. They are taken here as scientific concepts so that some of their underlying assumptions can be revealed and compared with each other in a content analysis (Ryan and Bernard, 2000). Hence, a hermeneutic methodology is applied, which builds on interpretivism as the ontological perspective taken (Lincoln and Guba, 2000; Schwandt, 2000; in relation to sustainable development see Welford, 1998). This allows a discussion of the limitation of domains as well as the relationships between related concepts (Wacker, 1998, p. 368).

A systems perspective is often used in sustainable development and is present in all four concepts (see e.g. Allenby, 1999a; Handfield and Nichols, 1999; Ehrenfeld, 2000; Pesonen, 2001). As such, systems of actors or companies have two specific features: (i) material (and information) flows and (ii) the actors and their co-operations involved, which is frequently referred to in definitions of SCM (see e.g. Handfield and Nichols, 1999; Seuring 2002a, 2004). The material and energy flows assessed (for simplification only addressed as material flows) occur within certain system boundaries and relate to different time frames applied during an analysis. This provides the first criterion for analysis and is related to the physical basis of the concepts, as system boundaries play a central role in delimiting the analysis conducted (Ehrenfeld, 1997; Isenmann, 2003; Seuring, 2004). The different time frame dominating in the concepts will be used as the second criterion.

The systems studied span more than one company (also Ehrenfeld, 2000; Heiskanen, 2000; Korhonen and Snäkin, 2001; Kogg, 2003; Seuring, 2004). It is valid to take a look at the actor networks involved in each concept and how inter-organizational environmental management is perceived therein. This criterion builds on the cooperation principle of sustainable development (Meffert and Kirchgeorg, 1998, p. 105). In SCM, this centres on the focal company that plays the central role in forming the network and often provides access to customers (Handfield and Nichols, 1999, p. 18; Schary and Skjott-Larsen, 2001, p. 24).

The actors involved in inter-organizational environmental management are embedded into an environment where stakeholders are important (Freeman, 1984), so they are also seen as relevant actors that form part of the actor network. Socolow (1994), Ehrenfeld (2000), Boons and Roome (2000) and Isenmann (2003) point towards the importance of human actors in IE, so that IE is not only an analytical instrument, but also a cultural phenomenon (Boons and Roome, 2000, p. 49). Similar issues are raised for life cycle assessment and its need to be comprehended as a managerial tool, i.e. LCM (Sharfman *et al*., 1997; Ehrenfeld, 1997; Heiskanen, 2000) within its institutional logic (Heiskanen, 2002, p. 427). For ICM and ESCM, this is addressed in a similar way (Bowen *et al*., 2001; Boons, 2002; Schneidewind, 2003; Seuring, 2004). This might also have been triggered by critics such as with the paper of Schaltegger (1997), who argued for the inefficiencies in the (still prevailing) approach towards life cycle assessment (one might add IE), which tries to solve too many problems at the same time. Hence, general data is used, which does not offer a solution to the individual problem that has to be tackled by a certain actor or firm. In sum, the criteria for the analysis are (i) actor network, (ii) material flow/system boundaries and (iii) time frames.

DEFINING AND ANALYSING THE FOUR CONCEPTS

Industrial ecology

Selected definitions are presented that are representative for the literature on the concepts. Also some further remarks for providing a basic background are given (see Tables 1–4).

Table 1. Definitions of industrial ecology

Author(s)	Industrial ecology (IE)
Frosch and Gallopoulos, 1989, p. 95	'The traditional model of industrial activity – in which individual manufacturing processes take in raw materials and generate products to be sold, plus waste to be disposed of – should be transformed into a more integrated model: an industrial ecosystem. The industrial ecosystem would function as an analogue of biological ecosystems.'
Graedel, 1994, p. 23	'Industrial Ecology (IE) is a new ensemble concept in which the interactions between human activities and the environment are systematically analysed. As applied to industry, IE seeks to optimize the total industrial material cycle from virgin material, to finished product, to ultimate disposal of waste.'
Ayres and Ayres, 1996, pp. 278–279	'Industrial Ecology is a neologism intended to call attention to a biological analogy: The fact that an ecosystem tends to recycle most essential nutrients, using only energy from the sun to "drive" the system. [. . .] In a 'perfect' ecosystem the only input is energy from the sun. All other materials are recycled biologically, in the sense that each species' waste products are the "food" of another species. [. . .] The industrial analogy of an ecosystem is an industrial park (or some larger region) which captures and recycles all physical materials internally, consuming only energy from outside the system, and producing only non-material services for sale to consumers.'
Korhonen, 2000, p. 19	'Industrial ecology has been understood as a material flow management concept for industrial companies. It will focus on the physical material and energy flows that a company uses from its natural environment as well as from its co-operation partners. It will focus on the flows that a company will produce as its waste and on emission outputs dumped back to nature.'

The paper by Frosch and Gallopoulos (1989) is seen as the initial trigger for industrial ecology. Rapid development has since led to the foundation of the International Society for Industrial Ecology, the *Journal of Industrial Ecology* and a second journal, *Progress in Industrial Ecology*. Erkman (1997) brings together some lines on how IE developed and points towards earlier lines of related research.

IE covers both a geographical and a product-based approach (Boons and Baas, 1997; Korhonen, 2002). The second approach is closely related to the subsequently discussed concepts, especially life cycle assessment (Ehrenfeld, 2003). The geographical approach centres on analysing local or regional networks of material flows such as in eco-industrial parks, 'industrial ecosystems' or 'industrial symbiosis' (Ehrenfeld and Gertler, 1997; Lowe, 1997; Côté and Smolenaars, 1997). This focus on geographic aspects is unique to IE, as this is not covered by any of the other concepts. Still, this kind of geographical approach is not limited to industrial ecosystems/symbiosis, but incorporates the link of human activities to natural ecosystems (Erkman, 1997; Ehrenfeld, 2000). This is well reflected in the four definitions selected (see Table 1).

In the definitions, IE, and in particular industrial symbiosis, which is focused on here, clearly implies a geographical approach. This is applied on a local or regional level. Relevant actors are the companies within an industrial symbiosis/industrial park, which organize the by-product or waste exchanges. Their co-location is seen as a prerequisite (Lowe, 1997). The system boundary is formed by the local or regional network of companies, and the material flows are organized within their specific network. Networks might develop over time (Ehrenfeld and Gertler, 1997) or be actively developed around an industrial core (Côté and

Table 2. Definitions of life-cycle management

Author(s)	Life-cycle management (LCM)
Linnanen *et al.*, 1995, p. 121	'Life cycle management consists of three views: (1) the management view – integrating environmental issues into the decision making of the company; (2) the engineering view – optimising the environmental impact caused by the product during its life cycle; and (3) the leadership view – creating a new organisational culture.'
Fava, 1997, p. 8	'Life cycle management is the linkage between life cycle environmental criteria and an organisation's strategies and plans to achieve business benefits.'
Heiskanen, 2002, pp. 428, 429	'LCA-based ideas and tools can be viewed as emerging institutional logics of their own. While LCA makes use of many scientific models and principles, it is more a form of accounting than an empirical, observational science. Thus, the life cycle approach implies a kind of 'social planner's view' on environmental issues, rather than the minimisation of a company's direct environmental liabilities.'
Hunkeler *et al.*, 2003, p. 19	'Life cycle management (LCM) is an integrated framework of concepts and techniques to address environmental, economic, technological and social aspects of products, services and organizations. LCM, as any other management pattern, is applied on a voluntary basis and can be adapted to the specific needs and characteristics of individual organisations.'

Smolenaars, 1997), but are also historically present at large industrial sites, e.g. in the chemical industry (Anastas and Breen, 1997) The material flows are dependent on the products produced and the processes used as a result. As the processes applied within a factory are often used over a longer period of time than when an individual product line is manufactured, the material flows are bound to the life cycle of the factory, usually in operation for years or decades (Schmenner, 1983).

Life-cycle management

Life cycle assessment (LCA) started around the mid-1970s (Hunt and Franklin, 1996; Oberbacher *et al*., 1996; Boustead, 1996) and led to the publication of an international standard on LCA in August 1997 (ISO 14040, 1997). While the aim of decision making existed from the early developments of LCA (Boustead, 1996), the need to establish a stronger link to managerial decisions has been put forward, captured in the term life-cycle management (LCM). A prominent example of this attempt is the final reports of the SETAC (Society for Environmental Toxicology and Chemistry) working group on LCM (Hunkeler *et al*., 2003) as well as a current working group on life-cycle costing (Rebitzer and Seuring, 2003). (See Table 2.)

The dominating approach in all discussions around LCM is the (environmental) product life cycle, which is used to structure the analysis carried out. Emphasis is placed on the product design phase, as 80% of the environmental burden and cost of a product is fixed during this phase (Rebitzer, 2002). This also implies that the analysis is often carried out during early stages of the life cycle to make the results applicable during the later phases.

Relevant material flows relate to the product life cycle. The assessment identifies the substances that enter the product and the related environmental burden (Boustead, 1996; Oberbacher *et al*., 1996). The product life cycle is also the unit of analysis specifying the time domain. Product life cycles span a wide range of duration, but for industrial consumer goods frequently last months to years. They might be much shorter or even inseparable from the operations process such as in service operation, or much longer, as e.g. usually is the case in building. The use phase therefore has to be integrated into the assessment. Material flows are systematically analysed and reported to yield an inventory of all flows involved (ISO 14040, 1997), but are frequently assessed independent of the single actor involved (Schaltegger, 1997). Related software tools and databases have been developed, which allow the use of average data in LCA irrespective of a single actor. Related problems are found regarding both data generation while conducting a LCA and application of the findings afterwards (Linnanen *et al*., 1995). Yet, the rise of LCM might be seen as a turn towards the actor (see e.g. the definitions above). Relevant actors are the companies that extract materials from nature or use the industrial process to create or modify them to yield the product. Interorganizational management plays a vital role, as environmental burdens occur outside the activities of a single company, so the single company is not able to manage them independently, but has to rely on the other companies involved in the life cycle (Heiskanen, 2000; Pesonen, 2001). This LCM implementation process has been rarely researched. Hunkeler *et al*. (2003) provide some hints on this, but do not offer detailed guidelines. As this need is now evident, it forms part of the activities of the life cycle initiative launched by UNEP and SETAC in 2002 (Udo de Haes *et al*., 2003).

Integrated chain management

The concept of integrated chain management has mainly been developed in The Netherlands and Germany. The initial trigger was given by public policy, e.g. the Dutch National Environmental Policy Plan (NEPP) issued in 1989 (Cramer, 1996; Wolters *et al*., 1997) or the Enquete-Kommission (1994) of the German Bundestag, which published its two reports on ICM in 1993 and 1994. There has been a rapid development in the field. Much of this is still owed to previous developments in LCA, from which the material-flow-based methodology was taken. This is applied in two different modes. One is the classical approach of LCA, while the second is the analysis of all sources, uses and links of a substance, such as in material flow analysis (Enquete-Kommission, 1994). ICM looks much more at managerial applications, but most clearly integrates the public policy level, e.g. legal acts that set the agenda, such as the German Closed-Substance Cycle Act and Waste Management Act (Kreislaufwirtschafts-/Abfallgesetz, 1996). The concept has been framed by political agenda setting, as the term was established there and then taken up in research (Seuring and Müller, 2004). (See Table 3.)

The extended scope of ICM compared with LCA (Seuring, 2004) is clearly expressed by the definition of the Enquete-Kommission (1994), which emphasizes the impact of stakeholders more than in any of the other definitions given for all four concepts. This is the distinctive feature of ICM, so that material flows are seen not only among direct actors of a chain or network, but as interrelated with society. This is somehow immanent to the other concepts (see e.g. Ehrenfeld, 2000; Pesonen, 2001). Stakeholders have a great impact on the wider environment a company operates in forming part of the actor network. Along with governments that enact environmental regulation laws, which have a great influence on corporate strategy (Matten, 2003), another example would be non-governmental organizations (NGOs) that put pressure on companies that supply materials manufactured under inadequate social or environmental conditions (Seuring and Goldbach, 2004). Hence, the typical time span is related to the societal environment and its institutional arrangements; this changes over decades (Minsch *et al*., 1998). Yet, companies are not passive neo-classical optimizers (see e.g the critique by Welford, 1998), but instead can and have to actively interpret their surrounding conditions and design their operations, actor networks and societal relations accordingly (Schneidewind, 2003).

Table 3. Definitions of integrated chain management

Author(s)	Integrated chain management (ICM)
Enquete Kommission, 1994, p. 549	'Integrated Chain Management (Stoffstrommanagement) is the management of material flows by stakeholders [to be] the goal-orientated, responsible, integrated, and efficient manipulation of material flows. Set targets derive from the ecological and economic realm, under consideration of social aspects. Goals are set on the level of the single firm, within the supply chain of actors, or on the public policy level.'
Cramer, 1996, p. 36	'Integrated Chain Management (ICM) is the integrated management of a supply chain in terms of the environmentally, socially and economically responsible management of the production, consumption, distribution and ultimate disposal of a product.'
Wolters *et al*., 1997, pp. 121, 122	'Integrated Chain Management (ICM) is the incorporation of sustainability considerations into supply chains and related networks. Integrated Chain Management has two main features. The first is the flows of materials which result from economic activities. The second is the institutional framework which shape the production and consumption processes driving the material flows. ICM considers the entire material cycle from cradle to grave – in one sense it is the organisational implementation of life cycle analysis (LCA). [Such life cycles or] product chains involve institutional networks of companies, consumers, professionals and other entities as well as material flows. ICM has to address both dimensions to be successful.'
Boons, 1998, p. 22, 2002, p. 496	'The framework for [integrated] product chain management, and the improvement of the ecological performance of a product, consists of three building blocks: (a) the product chain as a network of actors; (b) the options available to reduce the ecological impact of a product; and (c) assumptions about the behaviour of actors in the product chain.'

Environmental supply chain management

While all of the concepts mentioned so far clearly have their basis on the environmental science side, and many researchers in those fields have a natural science or technical background, this is not necessarily the case for environmental supply chain management (see Table 4.)

Such thinking emerged from research done by those with a management background. It is hard to spot distinctive lines of research here, as many problems are similar to those in 'normal' SCM. Still, one major debate in environmental management literature is reflected here (Wagner *et al*., 2001): the question of whether the overall performance of companies or supply chains implementing such an approach is improved, creating a win–win situation, or whether trade-offs between environmental (and/or social) and economic goals exist (Seuring and Müller, 2004). It is this managerial approach and emphasis on operational execution that emerges as a clear distinction to the other concepts. However, this is well in line with the efforts towards operational efficiency in SCM (Handfield and Nichols, 1999). Delivery cycles are a central time frame, so one day, a few days or weeks are the typical time periods considered.

The management of integration along the chain also plays a critical role (Handfield and Nichols, 1999; Mouritsen *et al*., 2003). Companies are here seen from their contribution towards customer satisfaction as the main goal of all supply chain operations. Hence, material and information flow integration takes place when needed to achieve this goal, while other

Table 4. Definitions of green or environmental supply chain management

Author(s)	Green or environmental supply chain management (ESCM)
Beamon, 1999, p. 337	'The fully integrated, extended supply chain contains all of the elements of the traditional supply chain (Figure 1), but extends the one-way chain to construct a semi-closed loop that includes product and packaging recycling, re-use, and/or remanufacturing operations.'
Bowen *et al.*, 2001, p. 175	'The term "green supply" indicates supply [chain] management activities that are attempts to improve the environmental performance of purchased inputs, or of the suppliers that provide them. Two main types of green supply can be identified. The first is termed *greening the supply process*, while the second is *product-based green supply*.'
Zsidisin and Siferd, 2001, p. 69	'Environmental supply chain management (ESCM) for an individual firm is 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.'
Rao, 2002, p. 632	'The concepts pertaining to greening the supply chain or supply chain environmental management (SCEM) are usually understood by industry as screening suppliers for their environmental performance and then doing business with only those that meet regulatory standards. The driving forces for implementing the concept into the company operations are many and comprise a range of "reactive regulatory reasons to proactive strategic and competitive advantage reasons".'

pre-production stages will be excluded and not be treated as part of the system (Mentzer *et al.*, 2001). To build such cooperation might take much longer, as capabilities need to be developed before the operational execution can take place (Bowen *et al.*, 2001; Seuring, 2003; Kogg, 2003), pointing to the managerial process required to form and maintain the supply chain. If environmentally improved products are to be introduced to the market, it might first be necessary to search for new suppliers and supplies, as described e.g. for organic cotton products (Seuring, 2001; Goldbach, 2003; Kogg, 2003). Relationships and their importance are widely discussed in ESCM, including some hints on the management process needed for them. This has been discussed using the example of various cases (Cramer, 1996; Seuring, 2001; Goldbach; 2003; Kogg, 2003), where it is pointed out that the costs and benefits of implementing such an approach are shared among the members of the supply chain. Focal companies might even set up preparation schemes where staffs from supplier companies are trained to meet the requirements set (Seuring and Goldbach, 2004). The managerial emphasis on this process is much more present in publications on ESCM than is the case for any of the other concepts.

COMPARING THE FOUR CONCEPTS

Table 5 provides a summary of the analysis of the concepts. Along with the three criteria mentioned above, it contains a column where the distinctive feature most prominently or only addressed in the particular concept is mentioned. The concepts are now listed from the longest time frame considered in a typical analysis to the shortest. It has to be mentioned that it is not intended to narrowly 'restrict' the application of the concepts discussed, but rather to point out differences that might contribute to future developments.

Table 5. Comparing the four concepts

Concept	Distinctive feature	Actor network	Material flows/system boundaries	Time frame
Integrated chain management	Stakeholder integration	Companies involved in and stakeholders affected by material flows	Material flows within their societal and legal boundaries	Societal and legal systems (decades)
Industrial symbiosis	Geographical approach/regional application	Companies involved in an industrial symbiosis	Material flows in a regional network	Factory life cycle (years to decades)
Life-cycle management	Product design as most important decision phase	All production stages involved in designing and producing products and services	Material flows that are related to a product life cycle	Product life cycle (months to years)
Supply chain management	Managerial activities needed within the actor network	All production stages directly involved in fulfilling customer demands	Operational material and information flows to satisfy customer needs	Supply chain development (months to years); delivery cycle (hours to weeks)

PROPOSING AN INTERRELATION BETWEEN THE CONCEPTS

All concepts have their validity both for the scientific arena, e.g. by furthering theory developments and the general comprehension of related problems, and for managerial applications, i.e. giving direction to managers in companies. The example of supply-chain-related discussions might help to clarify this. In a structured literature review related to the use of the terms 'supply chain' and 'supply chain management', Mentzer *et al*. (2001. p. 5) point out that at least three categories can be found: a management philosophy, implementation of a management philosophy and a set of management processes. For life cycles, this was expressed in a similar way as early as 1994 by Henn and Fava (1994, p. 549; also Heiskanen, 2002). Relating this to the terminology used in strategic management (Thompson, 2001), three levels can be distinguished: the management philosophy or mission level, the strategic level and the operational level. Clearly, all four concepts would cover all of these levels, but might have their strengths on different levels. This idea was partially captured in the analysis of the concepts, but is pictorially displayed in Figure 1.

The link to bio-geological cycles and how nature is metaphorically used (Isenmann, 2003) highlights how IE forms a natural system vision. As a philosophy and vision, it is kept in mind for all operational activities a company enacts, while the ideal state might never be reached. Second, a set of general conditions is set on the political level, which is most prominently expressed in ICM. Companies act in a legal environment, which can bring forward new legislation having a great impact on how materials are managed. An example is the Waste Electric and Electronic Equipment (WEEE) directive of the European Union, which obliges manufacturers of electrical and electronic equipment to take back old equipment for processing and recovery. While this is an example of extended producer responsibility (Lindhqvist, 2000; Mont and Lindhqvist, 2003), the (re-) actions taken by companies occur along the supply chain (see the example discussed by Spengler and Stölting, 2003). Non-governmental organizations as stake-

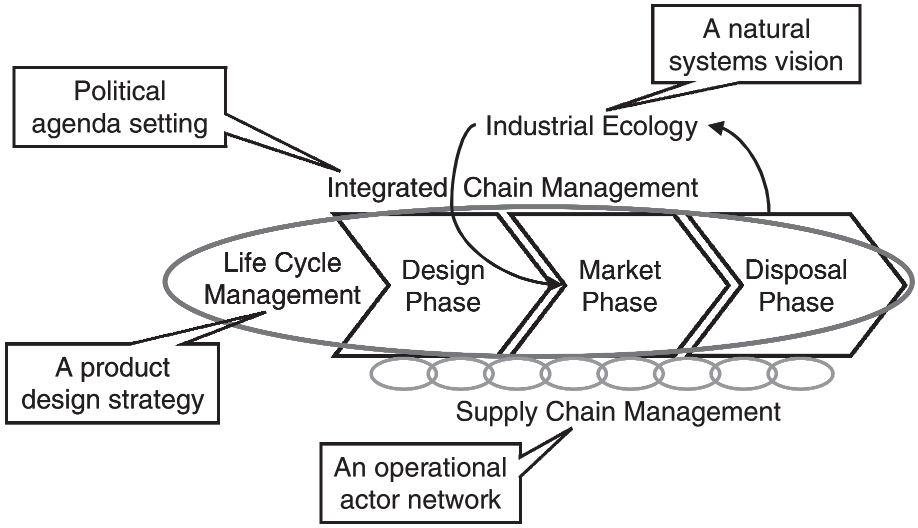

Figure 1. An integrative framework

holders increasingly demand companies to act according to global standards (Seuring and Goldbach, 2004). So it is not only the legal system, but the wider societal systems that have to be taken into account, as e.g. addressed in the policy framework for IE put forward by Allenby (1999b).

One step further towards the operational application of the concepts is shown in the metaphor of the life cycle, which highlights the need for a product design strategy that keeps all environmental consequences in mind while engineering a new product or service. While SCM also integrates product development (Handfield *et al*., 1999; Seuring, 2002a), its emphasis is nevertheless on a far more operational level. All operational activities which are needed to market products and services are therefore part of SCM, so this has to deal with the actor network of suppliers and customers a company is linked to.

CONCLUSION AND SOME DIRECTIONS FOR FUTURE RESEARCH

The issues discussed do not form a theory (Sutton and Staw, 1995), but they might contribute to theorizing (Weick, 1995). Sustainable development will not just happen on its own, but needs the action of many as well as competing conceptualizations and approaches to conceptualize and operationalize towards its implementation. Such actors are organized into economic institutions and therefore play a central role. The issues are emerging among all four concepts, all of which might contribute to the debate on sustainable development. Analysis reveals some joint lines, but also substantial differences among the four concepts. Of course, the conceptual developments have not reached an end to this point. This is even the case for e.g. the related discipline of SCM, where it is claimed that theoretical and conceptual research has to extend much further (Croom *et al*., 2000; Mentzer *et al*., 2001).

One important deficit found is the lack of guidance on how the concepts are to be applied among all actors involved. This does not ask for more checklists, which can be quickly applied, but for in-depth insights on how companies interact to jointly reduce environmental burdens. Managerial processes needed for such cooperation and the instruments applied have rarely been presented. Goldbach (2002) offers one example where the use of cost management tools, i.e. target costing, is described regarding the functional and institutional role it can play in a supply chain. With the example of target costing, Seuring (2002b) presents a case study from the apparel industry, where companies forming a three-stage supply chain, and the joint cost and operations measures taken to introduce an environmentally optimized fabric, were studied.

A wider analysis might compare or integrate the concepts with environmental management accounting (Schaltegger and Burritt, 2000; Bennett *et al*., 2003), extended producer responsibility (Lindhqvist, 2000; Mont and Lindhqvist, 2003) or corporate social responsibility (see e.g. Burke and Logsdon, 1996; Andriof *et al*. 2002). The achieved performance for all three dimensions of sustainability is of great interest. Here, a link to performance management literature and its recent developments in the environmental management debate form another supporting pillar (Wagner *et al*., 2001; Figge *et al*., 2002).

A possible joint contribution might also come from the research process and how researchers meet to discuss and exchange ideas. Even though the relations between the four concepts are evident, few researchers seem to cross this border. Of course, this should not be limited to the issues raised, but might include further topics such as environmental management accounting, eco-efficiency or integrated product policy. This might also lead to the development of theories enhancing sustainable development.

ACKNOWLEDGEMENTS

I would like to thank the participants of the Industrial Ecology Symposium at the 2003 Business Strategy and the Environment Conference, who greatly helped to improve this paper with their comments. Furthermore, the comments by three anonymous reviewers as well as discussions with the editors of this special issue have been very valuable in strengthening the ideas presented.

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