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# **The Environmental Implications of Electronic Commerce – The Assessment Approach Problem**

Sajed M. Abukhader

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*Division of Packaging Logistics*  
Department of Design Sciences  
Lund University

*An Updated Version*



# **The Environmental Implications of Electronic Commerce – The Assessment Approach Problem**

**Dissertation for the Degree of Licentiate in Engineering (Towards PhD. in Eng.)**

*– based on a collection of four research papers and a covering summary report*

**Paper 1:**

*“The Environmental Implications of Electronic Commerce – A Critical Review and  
Framework for Future Investigations”*

**Paper 2:**

*“E-commerce and the Environment: A Gateway to the Renewal of Greening Supply Chains”*

**Paper 3:**

*“Eco-efficiency in the Era of Electronic Commerce – Is There a Need  
for Adopting ‘Eco-effectiveness?’”*

**Paper 4:**

*“Logistics and the Environment: Is it an established subject?”*

**Sajed M. Abukhader**

Division of Packaging Logistics  
Department of Design Sciences  
Lund University, Sweden 2003

# The Environmental Implications of Electronic Commerce

## – The Assessment Approach Problem

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Sajed M. Abukhader – Lund, May 2003





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## EXECUTIVE SUMMARY

### Introduction

A doctoral dissertation or a Licentiate (a degree towards the Ph.D.) dissertation at a Swedish university is either produced as a monograph or as a collection of papers. In the latter case, the introductory part represents the executive summary of the appended papers written in a more likely narrative way. I have chosen to follow the latter form of dissertation as I have already formulated my work into four papers (submitted/published in journals).

This section paves a quick entrance to the issue of the environmental implications of E-commerce. In the beginning, though, simplified definitions of some selected terms are listed here due to the reason that there could be audiences from several disciplines mainly: Logistics/Supply chain management, Production management, Business, and Environmental management. The selected terms are presented next.

#### *1. Terminology*

*Supply chain:* “A set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances and information from a source to a customer” (Mentzer et al., 2001).

*Supply chain management:* is a concept “whose primary objective is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers” (Monczka, Trent, and Handfield, 1998). (There are several definitions among the authorities in this discipline; however, I preferred to select the least complicated that a foreign audience to this discipline can grasp easier)

*Logistics:* According to the Council of Logistics Management (CLM, 2002), “logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customer’s requirements”. A logistical system, therefore, includes mainly four main processes: transportation, warehousing, inventory management, and order processing (Pfohl, 1990; and Lambert, 1998).

*Packaging*: One concise definition is the following: “Packaging is a coordinated system of preparing goods for safe, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal combined with maximising consumer value, sales and hence profit” (Saghir, 2001).

*Business-to-business (B2B)*: This represents the business-only transactions, simply within the span from supplier to manufacturers to wholesalers to retailers/intermediaries. This is considered a part of the total supply chain.

*Business-to-consumer (B2C)*: This represents the transactions between the businesses and the consumers who use and consume the products to the end of life of these products. In fact this term is sometimes used to indicate the transaction between the retailers and consumers only, or sometimes to cover the whole transactions between any business type, for example wholesaler or manufacturers with the consumers.

*Environment*: There are several definitions for the term “environment”. One international definition is the one presented within the frame of the ISO 14004 International Standards: “*Surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelations. NOTE–Surroundings in this context extend from within an organisation to the global system*” (Cascio et al, 1996). In the Longman Environmental Dictionary for the environmental glossary, there is another definition as: “*The sum total of external influences acting on an organism*” (Lawrence, 1998). In the same dictionary, the definition of the term “environmental impact” might clarify that more: “The changes in the total environment, both in terms of the ecology and the social impact, caused by human activities” (Lawrence, 1998), whereas the term “environmental science” is: “the study of how humans and other species interact with their non-living and living environments”. In general, the word “environment” here refers to the body of knowledge of environmental science, which consists mainly of three disciplines: environmental engineering, environmental management, and the science of ecology. A main concern in this arena is the study of the interactions of human beings with the living and non-living natural resources. These sciences attempt to understand how to utilize the man-made systems of the civil infrastructure including systems for production, logistics, transportation, packaging, and other systems, in environmentally responsible manner.

*Industrial ecology*: The primary objective of this concept “is to interpret and adapt understanding of natural ecological systems and to apply the most beneficial of these concepts to the acquisition of human made systems such that they become efficient, effective and sustainable” (Sage, 1997).

*Design for Environment:* “The activities undertaken when a product’s design is to reflect environmental considerations in the entire life cycle of the product in order to increase product competitiveness, add to the market value, decrease the cost of ownership, or meet existent and future environmental regulatory demands” (Karlsson, 2001).

*Life Cycle Assessment:* It is the most commonly environmental assessment method in the field of environmental management normally conducted on a specific product vis-à-vis another competitive product in the market. This tool assesses the environmental implications of the product across its whole life cycle from cradle to grave.

## 2. Background

There are new terms emerging and spreading by this millennium: Information technology, Globalisation, Internet, Electronic commerce (E-commerce), ICT, Teleworking, Dematerialisation, Teleconferencing, and more. These terms are in one pool: *the era of Digital Economy*. People, industry, government – the different levels of society – are using and talking about these terms. The concern is that there are beliefs that the new communication methods of information technology and Internet will build up a considerable momentum towards the sustainable development. There are, though, some voices in society that disbelief in this and rather stand against it.

As one of those hot issues of information technology, E-commerce (or called sometimes E-business) has increasing trends as an extra trading channel of transactions among the industries (B2B), and between the consumers and the total business sector (B2C) (Abouzeedan et al., 2003). Such transactions are expected to influence a wide range of man-made systems of the industrial infrastructure including systems of manufacturing/production, transportation, packaging, warehousing, yet to unknown extent and form. For example, one central hope in E-commerce is that supply chains of miscellaneous merchandise will be shortcut. This is by performing faster delivery of products with less number of nodes in the middle, in the meaning that such nodes, i.e. large and small retailers and wholesalers, and even distribution centers, vanish in the long run. This may ultimately lead to direct deliveries from the manufacturing company to the consumers (Caudill et al., 2000; Davis, C., 2000; Li, 2001; and Hurst, 2001).

The total literature on E-commerce and environment indicates that there are both negative and positive environmental implications, with a high difficulty to weigh them over each other (Joint Symposium on E-commerce and Environment, 2000). Proponents of E-commerce expect there will be considerable environmental benefits such as decrease

of paper consumption, decrease of fuel consumption, reduction of size of stores/offices/warehouses, decrease of transportation flow, etc. On the other hand, opponents are pessimistic about some significant negative environmental effects such as increase of human orders and amount of shopping, increase of electronic waste equipment, more use of faster-mode transportation (often use of airfreights) to farther destinations, etc (Leahy, 2001). Some opponents were even pointing to hidden unexpected effects such as consumption of erbium minerals, which are necessary in building the cable structures of the wide band Internet communication.

“Modern E-commerce will influence not only the delivery of goods, but also stores, warehouse space and perhaps also the way people use their time and how they travel. How this influence will develop must be understood to ensure that proper initiatives are taken both by companies and official agencies to develop distribution and transportation systems and a strategy for sustainable development in areas affected by the increasing use of the Internet. It will therefore be of utmost importance to identify and study which areas will undergo a change due to E-commerce and the use of Internet, and in what way the changes will create new systems for transportation or changes in the old ones. E-commerce must be considered in a global perspective, as suppliers and consumers may function differently on different continents. This means that it is important to ensure that the understanding of differences and experiences from several countries be utilized as much as possible.” (Jönson et al., 2000).

What do all that mean from an environmental point of view? Many questions need answers. Are the trends of transportation going to change dramatically? What about the type of transportation? Will the railway system get enhanced and become competitive to the heavy truck system? Or is it the airfreight system going to increase and play a significant role in delivering orders? Is the industry going to increase or decrease the amount and variety of products? Dematerialisation: would E-commerce contribute “positively” in this side? What about energy consumption? Miscellaneous questions have been raised.

No doubt that several disciplines are intervening in this regard. The trading system in the society, the economical system, the systems in supply chains, the human behaviour, and the technological development in general are all pulling the ropes. This makes the future scenarios very difficult to be predicted if not impossible.

## Scope and Research Objectives

### *1. Funding Framework*

The research work of this Licentiate was launched under the funding framework of the Swedish Agency for Innovation Systems (VINNOVA) with collaboration of three Swedish universities:

1. Chalmers University of Technology: (The group is lead by Prof. Kenth Lumsden)
2. Linköping University: (The group is lead by Prof. Mats Abrahamsson).
3. Lund University: (The group is lead by Prof. Gunilla Jönson)

The purpose of collaboration of these universities was to discuss the issue of E-commerce from three different perspectives with an interdisciplinary profile:

1. Focus on the flows and distribution systems in supply chains,
2. Focus on the changing roles in marketing channels, and
3. Focus on the packaging and the environmental implications.

### *2. Research Objectives*

As normally for any design implementation work, an assessment task precedes. The assessment activity is necessary and of a high benefit if we can simulate what would happen before implementing a design. The assessment gives some insights about the possible risks in the future and the spots of highest concern. Nevertheless, of course, the assessment activity is also of importance after the implementation, for the sake of continual improvement.

The very pilot study made within the proposal of the VINNOVA project indicates there is no established background or even a clear understanding regarding the assessment issue. The theories in the literature seem diverging and sometimes contradictory, with even confusing use of terms: Internet, E-commerce, Information technology, etc. Accordingly, the research objective of this Licentiate has been to:

*... gain some understanding about*

- *the possible tools of assessment*
- *why there are diverging theories and little agreement*
- *what proposals for the enhancement of the assessment activity can be suggested*

The ultimate aim of the whole work of my PhD (Licentiate + post Licentiate) is to:

1. Contribute in structuring this new arena of research, *and*
2. Build a “toolbox of approaches” for dealing with this type of interdisciplinary questions.

### 3. Scope and Limitations

The main focus in this Licentiate is studying the environmental implications of only E-commerce. I did not consider any other type of information technology. For example, studying the environmental implications of Internet is not considered in my work. It happened in the literature that some proponents of information technology mix between the Internet and E-commerce as if it is one issue; and it is not in fact. This point is clarified in the sequel with support of Figure 1.

Some of the main terms often used nowadays are IT (Information Technology), ICT (Information and Communication Technology), EDI (Electronic Data Interchange), and Internet. “For simplification purposes, to find out where E-commerce lies among this landscape, the above four terms (IT, ICT, EDI, and Internet) are presented as follows:

- The term ‘IT’ is included already in a larger term, which is ‘ICT’. So, (ICT = IT + Telecom). This context includes the hardware such as computers, telephones, televisions, cables etc. and the software that run them. This is the *equipment* part of the ‘ICT’, while the *application* part of ‘ICT’ is for example teleconferencing (both audio-conferencing and video-conferencing), teleworking, etc. (Arnfolk, 2002).
- ‘Internet’ is just one form of ‘IT’. Whereas personal computers, cables, softwares, etc. are the *equipment* of ‘Internet’, the *application* side (the use) of ‘Internet’ is experienced in many aspects of daily life: chatting, researching, mailing, advertising, trading, presenting oneself, etc.
- E-commerce (trading through Internet) is a phenomenon of ‘Internet’. However, in ‘EDI’ applications we find also E-commerce. So, E-commerce is also a phenomenon of ‘EDI’, which is a type of ‘IT’” (Paper 1).

“A concluding remark for the above tree is that any study performing assessment of environmental implications of Internet or environmental implications of IT is not considered an assessment of E-commerce alone. Moreover, although E-commerce is just one of the aspects that such an Internet study covers, it does not cover all E-commerce interactions. Studies performing environmental assessment of IT are expected to include all E-commerce interactions. This is a point of importance as the reader finds different titles of assessments with different term use (IT, ICT, Internet, EDI, E-commerce). In the literature, one can meet several e-prefixed terms (e-business, e-logistics, e-supply chain, e-fulfilment and e-procurement), which are used in the field of supply chain management (SCM). ‘E-business’ is just another name for E-commerce” (Paper 1).

Another demarcation is that my work did not discuss the implementation of environmental technology when designing E-commerce infrastructure or application.



The work discussed only the assessment issue of environmental implications. Two ways can be for this issue: perform an assessment, or study how to approach the assessment. I worked with the second. I did not perform an assessment. I only discussed and examined the assessment issue itself.

Moreover, I discussed and proposed a model, only for the assessment of the secondary effects (there are three types of effects regarding the environmental implications as will be explained in Paper 1). I did treat neither the primary effects, nor the tertiary effects. The three effects or say components within the assessment picture are in brief (Tuerk, 2001; Fichter, 2001):

- Primary effects (impact of building an infrastructure for E-commerce – terminal equipment hardware and software, servers, network infrastructure, etc.)
- Secondary effects (impact of the use/application of E-commerce, which means influence over systems of transportation, warehousing, packaging, etc.)
- Tertiary effects (impact of rebound effects, which have to do mainly with the change of human behaviour such as change in consumption patterns, new habits, etc.)

This choice of focus on the secondary effects is not due to any reason of importance or ranking among the three types of effects. The words “primary”, “secondary”, “tertiary” do not indicate any ranking or weighting of importance among them.

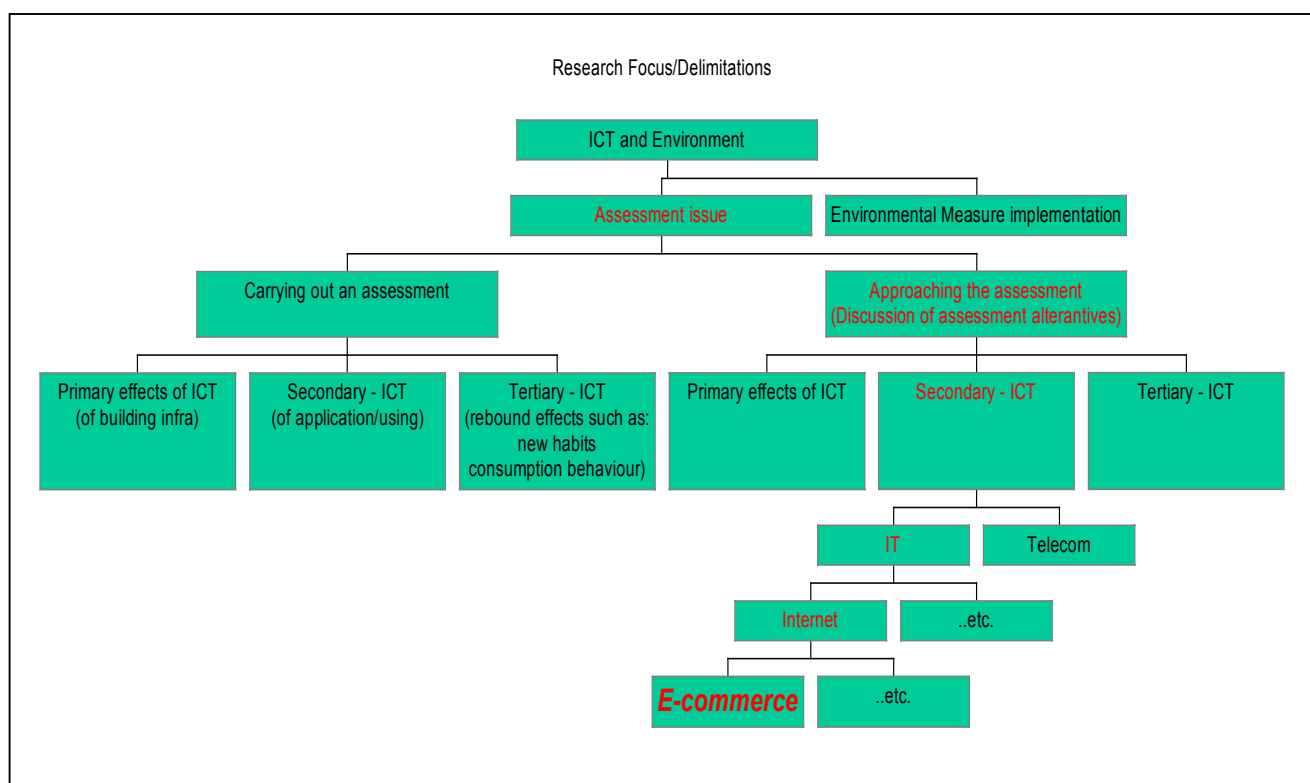


Figure 1. The research demarcations and focus

## Methodology

This section is concerned with presenting how the research work of this Licentiate has been approached and its reliability.

### *1. Introduction*

Principally, scholars in the environmental management field associate themselves to a discipline either in natural sciences or the human/social sciences. This is because it has to serve one of the established sciences and does not serve itself as the case with other fields/disciplines. One similar opinion (Parker, 1998) also believes that “environmental management (...) is too young a science, if it is a science, to be regarded as a discipline itself and, therefore, must be a combination of different disciplines”. This seems a challenging task, as it is definitely interdisciplinary always. But the more challenging is that scholars find a situation to discuss the possibilities for environmental management for the serve of one human/social science together with one natural science, and not separately. This is in fact the case that I am dealing with, i.e. E-commerce. In this situation, I had to find a platform to launch the research work from; simply, I had to find my “paradigm”.

In the environmental management field, Industrial Ecology and Design for Environment (DFE) are some of the core subjects, while the Life Cycle Assessment (LCA) and ISO14000 International Environmental Standards are considered core assessment methods/tools. Generally, working in this arena is likely considered to belong to the school of “Systems Approach”, which is one of three competitive approaches nowadays (Arbnor and Bjerke, 1997) recognised at least in the social and human sciences: “Analytical Approach”, “Systems Approach”, and “Actors Approach”. The main core differences between these three schools are that:

- Analytical approach assumes the whole is the sum of its parts, and assumes the knowledge as being objective and can be replicated.
- Systems approach assumes existence of synergy among the parts, meaning that the whole is not only the sum of its parts but also the relationships among them.
- Actors approach assumes reality as a social construction, and that knowledge is subjective being dependent on the actors themselves.

The work of my research is rather a group of systems-oriented studies, in which the attempt is to gain a realistic picture of the situation by envisioning a model that visualise how things are organised, categorised and related to each other. The work is based on

collecting as much history and information as possible searching for intervening relations among the components in “this picture”. In comparison, the analytical-oriented studies use statistical analyses and forecasts more, while the actors-oriented studies have its own unique techniques and way of interpretation of reality.

The research work of this Licentiate comes under the “pure science” type (or “basic science”) vis-à-vis “applied science” type. Definitely, each has its value; the practical realisation of value in the first type, though, is a long term issue. In fact, the importance and value of research in this Licentiate stems from the fact that this is an emerging area of knowledge (E-commerce & Environment). Its “ground” is calling for establishing theories for understanding the environmental implications of information and communication technology in general and E-commerce in particular.

If one form of start of a research work can be by deduction, another start can be by induction. One research path might undergo the use of the current established theories in the arena to back the application of a type of data collection method (quantitative or qualitative) for the sake of explaining the complications/questions (Deduction). In case of un-established arena, another path can be to proceed for a process of proposing and developing constructs, models and any “fruitful, useful” thinking (Induction), which should be transferred to a next stage of testing the use of these constructs or models in explaining or providing understanding regarding the questions/objectives (Abduction = induction and deduction). I can say that I was in a position of using an “inductive thinking” to motivate the work. Therefore, the work value that can be realised from this Licentiate is located in my effort to:

- Contribute in structuring this area of non-existing established background, *and*
- Offer ideas, models and thoughts for a next developing research stage.

It is often the case that such type of research begins with a group of pilot/short studies as a starting step.

## *2. Methods, Trustworthiness and Reliability*

The research methods utilised in this Licentiate were:

1. **Literature review** on E-commerce & Environment issue, accompanied with an evaluation discussion of the methodological aspects/gaps. The aim here was to get a good grip of the theories in this issue, and to “problematise” to reach a research focus (Paper 1).
2. **Content analysis** in 29 journals (last ten years). The reason was to find the possible approach available in the subject of “Logistics/SCM and Environment” for the use in “E-commerce and Environment”. However, the major discussion focus of

the paper turned out to be on questioning if “Logistics/SCM and Environment” is an established subject (Paper 4).

3. **Conceptual modelling** several times during the stages of the work (as can be seen in Paper 1 and Paper 2). This modelling accompanied a *process of abduction* (inference/induction and deduction afterwards). The evidence to support the modelling discussion is brought from the literature of several disciplines: supply chain management, production management, environmental management, etc. This process resulted in a proposal of a novel model.
4. **Survey of expert opinion** followed by a *tentative carry out (examples)* of a horizontal environmental assessment (Paper 2). The framework of this task includes a *discussion on directions for empirical methodology* (external validity) of the proposed model. The total work of this paper is built by using *concept development method*.
5. **Comparative evaluation** of the possible performance success or failure of two terminology, eco-efficiency and “Eco-Effectiveness” (which is still a metaphor). A *data-triangulated literature search* and *content analysis* methods were conducted. This work is in paper 3.

(The reader is advised to read the next section on the path of the total research work, in addition to the papers themselves; this will provide some insight why some methods have been chosen and the limitations of each method.)

The reliability and validity are some of the important aspects of testing the trustworthiness of the research work (Wallén, 1991; Arbnor and Bjerke, 1996). The reliability of a research work is the degree of accuracy of the measuring device/tool that we used for collecting data, whereas the validity is the appropriateness of this measuring device/tool. So, in the reliability issue, the need is to check if different scholars than the authors are able to reproduce the same results using the same technique/tool (Bouma, 2000).

For the literature review, it was of the type of finding out if there are any contradictory/conflicting results of assessing E-commerce. Generally, this is considered a strong type of literature review, because it persuades the audience that we need research. The weakest type of literature review is the one where the researchers present the information they collected and then claim that “there is a lack of research in this and this”. This is because it is pretty hard to convince the audience that the search process did cover every possible literature (Larsson, 2001).

For the content analysis method used in paper 4, it was done extensively in 29 journals selected within the last ten years (1992 – 2001) across several disciplines that

would touch upon the subject of 'Logistics/SCM and Environment'. The content analysis method is a type of observation work but in text (can be in television/video/audio material) (Bouma, 2000).

Most important of all methods was the conceptual modelling practice. This formed the most important stage of my learning and development of research skills. In this method, one should normally use plenty of carefully selected literature regarding the proposed concept, and likely this involves less amount of empirical evidence (Hilmola, 2003). Within a cycling process of abduction (induction/inference and deduction), I was trying to find out relationships between the observed data/facts and constructs I was proposing and developing. This was practised in Papers 2, and 3. Each time, there was a puzzling question along with some available observations. The target of my modelling each time was to achieve some of the common characteristics of a "good" model.

Some of these characteristics are (Bouma, 2000): Closely tied to observational base; Able to predict some relationships; Contribute with some understanding; Simple and convenient; Lead to some further new ideas and hypotheses; etc. Models, in general, are definitely not perfect and never complete and sometimes tentative, however these negative aspects are in fact common of any "good" model. In paper 2, I have been proposing and developing a new concept, that is "horizontal assessment", mostly discussing the internal validity. For the external validity, there was a limited opportunity only by introducing two tentative examples, which are not seemingly possible to be replicated. The hope is that in the next stage of research (post Licentiate) there will be possibilities for verifying the empirical side of the model.

The triangulation of data (qualitative) in paper 3 is one of four types of triangulations: methodological triangulation, theory triangulation, investigator triangulation, and data triangulation (Denzin, 1989). Reasons behind using triangulation were:

1. It was difficult to immediately find information about the definitions of "environmental efficiency" and "environmental effectiveness".
2. Acquiring data from multiple sources through data triangulation has a significant advantage for the trustworthiness of the work.

## The Research Path and Contribution

This section and the next section on conclusions aim at first:

- describing the steps and sequence of the research work, then
- concluding my propositions, beliefs, and views, and last
- suggesting tasks to continue the research work of the project.

My total contribution in this dissertation is realised in five things:

1. Organising the literature on “E-commerce and Environment”, which seems to confuse the readers, ..... *Paper 1*
2. Presenting a proposition regarding the issue of E-commerce, ..... *Paper 1*
3. Conceptualising and proposing a novel model of two-dimensional environmental assessment, ..... *Paper 2*
4. Showing that there is a need for considering the characteristics of “Eco-Effectiveness” metaphor in the era of E-commerce, ..... *Paper 3*
5. Discovering the subject of “Logistics/SCM & Environment” and the gaps in it. .... *Paper 4*

I see my work in the way it looks in Figure 2. Paper 2 is the core of this Licentiate, while Paper 3 sits at a second order of importance. Meanwhile, Paper 1 and 4 are considered auxiliary supporting papers.

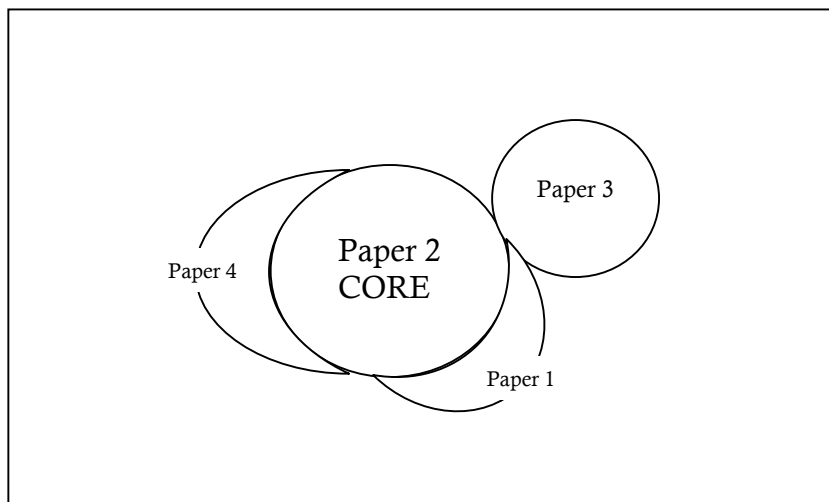


Figure 2. How I see the total work of my Licentiate

## *1. The Early Stage of this Research Work*

The problem awareness of this work at the very starting point was that:

1. There is an increasing number of stores transforming/newly building E-business infrastructure, closing down old locations and expanding in different forms of distribution,
2. In the same time, there are optimistic views that Information Technology (IT) will “drive” us towards sustainable development through the gate of “conservation of natural resources”.

Consequently, the question was: Is E-commerce an environmentally responsible choice for the future?

From a Systems Approach point of launch, the research route in this case will not be explanatory but rather exploratory, where a lot of information and history have to be acquired first of all. Several small, guiding questions will sequentially be raised. All that will help reach demarcated researchable objectives. My first task performed was to get acquainted with the work done to date by reviewing the literature in the issue of E-commerce and Environment. Two main concepts are driving the whole project: “E-commerce” and “Environment”. As a result, some sub-tasks were planned:

- What are the available definitions of E-commerce?
- What is the difference between IT and E-commerce (in addition to some other terms like ICT, EDI, E-business, Internet, Teleworking, etc.)?
- What are the components inside the “picture” of the issue of E-commerce?
- What are the available definitions for the term “Environment”?
- In order to select a reasonable approach for assessing the environmental implications of E-commerce, we need to find a reasonable angle to look at E-commerce from? (Finding the discipline belonging)
- How did researchers to date approach the assessment of its implications?

Some of the main findings at that time were that (Paper 1):

- Life Cycle Assessment (LCA) (and other gaseous emissions data assessments) has been chosen as an approach to bring some insights about E-commerce and Environment. However, there were problems of getting ungeneralisable/inconclusive results.
- Trying to find other possible approaches, I sought first a potential angle to look at E-commerce from, providing that E-commerce is a subject of interest for several different disciplines. A reasonable angle to look at E-commerce from is found to be the Supply Chain Management (SCM) discipline.

Upon that, the next sub-task was to learn:

- What are the available tools for environmental assessment in the subject of “Logistics/SCM & Environment”?

One of the findings was that (Paper 4):

- LCA is the commonly used method for this purpose.

## *2. The Main Stage*

So, “approaching the assessment of the environmental implications of E-commerce” became to me by itself a focus point to learn about, as a research objective. Why did the current LCA assessments (and some other “sister” assessments) provide conflicting/ungeneralisable results? Paper 2 discussed the theoretical background and proposed a novel model of assessment, while Paper 1 had carried the seeds for the new thinking of this proposed model. The model suggests that the assessment should have two dimensions: “vertical” and “horizontal” assessments, with the problem that the “horizontal” axis of assessment (due to its structure) needs sufficient support from the field of “SCM and Environment”, which is itself unfortunately stagnating and needs to be redirected. This is kept as an opening for a promising post work.

A further thinking had to be made to find a new task to attack E-commerce problem through. One observation inside the literature was that some researchers have, instead of using a specific tool like LCA, discussed E-commerce from a consumption point of view: consumption of materials, consumption of electricity, consumption of paper, etc. So, the new tasks were focused on (refer to Paper 3) reviewing the literature further on this direction of discussions (i.e. “consumption point of view”). The preliminary finding suggested that dematerialisation could be an interesting topic to link E-commerce problem with through the terminology: environmental efficiency and effectiveness. Consequently, I went for reviewing the fundamental knowledge established in the field of Environmental management in order to find some ropes. Some rewarding observations were cultivated when a comparative evaluation was done between the success and failure of eco-efficiency and “eco-effectiveness” in the era of E-commerce.



## Implications and Conclusions

### 1. Overall Concluding Remarks

Out of the total work, I believe that: *we should look for something else than the current traditional way of assessment*. The proposition has the vision: *instead of looking at E-commerce as “a vehicle driving towards freely satisfying the market needs, we should look at E-commerce as “a cart attached to our vehicle towards sustainable development”*. In other words, we need to “design the end” and work towards that end instead of keep things move freely to unknown future and stay assessing and comparing with “this” unknown. The driving factor nowadays for establishing an E-business is the profits, regardless of any environmental effects that would result. The environmental concern has to take place now before it becomes late in the future to implement any environmental measures. The helping factor is that we are still in the early stage of having E-commerce as a potential effective trading channel. I believe that this understanding is more important than the assessment performance task. One reason is that E-commerce, as explained earlier, is a phenomenon of Internet, which is spreading all over the globe anyway. Another reason is that the assessment problem is usually very complex such that the results will not be reliable, and almost never possible to generalise. So, the assessment performance is of little benefit at this stage. Still, this dissertation suggests a new way of carrying out assessments to alleviate the complexity, recommending *adoption of a two-dimensional model (vertical and horizontal assessments) instead of the current traditional way of assessment*. This is presented in Paper 2. However, this model is yet to develop further and it will be valid and highly important if the “greening supply chains” subject takes a new direction of research (refer to Paper 2).

The benefits of this new assessment model can be summarised in the following three elements:

- 1      Rehabilitate the subject of “Logistics/SCM & Environment”
- 2      Empowering further the LCA tool
- 3      Alleviating the complexity of assessing issues such as E-commerce and information technology

Looking at E-commerce issue with another lenses, that is dematerialisation, this research work suggests that we have to approach a higher ambition level of industrial understanding by a renewal of the term, Eco-efficiency. The need is to consider the advantages of the term Eco-effectiveness. This need is based on my argument that eco-efficiency will not help us “win” the dematerialisation potentials of E-commerce; we have to benefit from the thinking in eco-effectiveness.

Summary of the total conclusions follows:

1. Instead of looking at E-commerce as “a vehicle driving towards freely satisfying the market needs, we should look at E-commerce as “a cart attached to our vehicle towards sustainable development”.
2. A “Design the End” policy has more value for treating E-commerce at this stage than an “Assess and Watch” policy.
3. We have to change the way of performing environmental assessment from a traditional one-dimensional assessment to a two-dimensional (vertical, horizontal) assessment. This proposed model of two-dimensional assessment represents an innovative support to the Life Cycle Assessment method regarding assessing the environmental implications of E-commerce.
4. By considering Eco-effectiveness metaphor, a new type of environmental control [*“Eco-effectiveness and System Type III – ‘waste elimination’/ ‘functionality, not possession of products’”*] should be contemplated for the era of E-commerce *vis-à-vis* the current type of control [*“Eco-efficiency and System Type II – ‘waste reduction’/ ‘satisfy consumers’ needs’ ”*].
5. For a better realisation of dematerialisation in the era of E-commerce, it will be interesting to connecting the emerging environmental control approach, “Eco-effectiveness”, with the policy “Design the End”.
6. Currently, “Logistics/SCM & Environment” subject has been treated less than the other established subjects in the logistics discipline such as the management science, the business science, the information technology, etc. In addition, this subject seems stagnating, and actually needs re-directing and “rehabilitation”.

## 2. The Continuation Work

The direction of my work may either stay the same by keeping the **focus** on “E-commerce & Environment” topic, or may get diverted into **another focus**: “The Horizontal Assessment Model”.

**For the first focus.** There seem to be two windows of opportunities (out of the two core papers of this Licentiate – no. 2 and 3) for the continuation of the research towards the PhD dissertation:

- *Packaging, E-commerce and the Environment*
- *Packaging and Eco-effectiveness*

In the first window, the work can be towards:

- a) Learning about the “good” ways and “bad” ways in the influence of E-commerce on packaging systems from an environmental point view,

- b) Learning about the role of the packaging-related strategies (such as postponement, differentiation, etc.) in this whole picture,
- c) Learning about the possibilities for environmental measures against the possible negative implications of the E-commerce influence on the packaging systems from a “strategy point of angle”.

The second window of research opportunity can be towards:

- a) Learning about the possibilities and obstacles for the implementation of eco-effectiveness thinking on packaging, and
- b) Learning about the possibilities with E-commerce in this respect.

One reason to select packaging among several other large-scale processes is that packaging waste is one of the hot environmental issues especially in the industrial world (NyTeknik, 2003). In the European scale, there are tough legislations recommended. Even there are expectations that the EU Packaging and Packaging Waste Directive might fail, due to the difficulty of reaching the goals presented in the Directive (EUROPEN, 2002). It will be interesting to study the challenge of E-commerce to the packaging issues. Some demarcations for the studies shall be the following:

1. Focus on the grocery sector or more likely fast-moving-consumer grocery (FMCG), where the most packaging bulk is experienced,
2. Within the frame of B2C (retailers to consumers),
3. Including those businesses that transfer from traditional to electronic (or mixing both), excluding those launching electronic business from the very start.

**For the second focus.** The whole PhD work can be in the following different framework:

“Logistics & Environment – Developing A New Assessment Model”, taking:

- E-commerce technology as a case for verifying the internal validity (theoretical validity)
- Postponement strategy as a case for verifying the external validity (empirical validity). The work in postponement can be demarcated to a specific industry such as the Food industry.

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# PAPER 1

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# The environmental implications of electronic commerce

## A critical review and framework for future investigation

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**Keywords** *Electronic commerce, Environmental management, Energy consumption, Internet*

**Abstract** *There are accelerating trends for the implementation of electronic commerce (e-commerce) as an extra marketing channel for selling products globally via the access of the Internet. This is expected to influence the shape of future cities and the conservation of natural resources. This paper critically reviews the current research work to date regarding the environmental implications of e-commerce. The main observation is that there are difficulties to generalise the results. There is a general agreement that it is highly difficult, if not impossible, to state if the damaging effects of e-commerce on the environment can weigh over the advantageous effects or the contrary. One proposition in this context is that instead of looking at e-commerce as "a vehicle driving towards freely satisfying the market needs", we should look at e-commerce as "a cart attached to our vehicle towards sustainable development".*

### Introduction

There are accelerating trends for the implementation of electronic commerce (e-commerce) as an extra trading channel, through which products are marketed and sold globally via the access of the Internet (OECD, 2001). This is expected to bring changes over the traditional shape of urban infrastructure in terms of production systems, logistics systems, transportation systems, packaging systems, warehousing systems, etc. This intuitively leads to environmental implications that we need to investigate and acquire adequate knowledge of before environmental abatement measures become difficult to implement in the future. We are witnessing serious obstacles to implementing environmental measures for several urban concerns (such as noise in cities, air pollution, electronic products waste, to mention only a few) due to reasons such as high costs, difficulties in rebuilding the existing infrastructure, etc.

This paper critically reviews the current research work to date on the topic of "e-commerce and environment". The main aim was to organise the picture about this issue, as the reader often finds interventions among the different components of the issue. Another aim was to shed light on the problematic use of methods leading to difficulty in generalising the results, and propose a framework for future investigation.



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### *E-commerce*

There are several definitions and understandings of e-commerce (Aldin and Stahre, 2003). One definition is of the European Commission (1998), that is:

[...] any form of business interaction in which the parties interact electronically rather than by physical exchanges or direct physical contact.

Another close definition is:

[...] a critical component of supply chain management that includes the conduct of any business transaction using digital rather than physical means (CLM, 2002).

“E-commerce is regarded as one of several marketing channels, including the use of the Internet, to support inter-organisational processes, such as marketing, ordering and related service activities” (Aldin and Stahre, 2003) within both business-to-business (B2B) and business-to-customer (B2C). One simplified definition of B2B and B2C can be as follows: B2B covers the flow of products from suppliers to manufacturers to wholesalers to retailers, while B2C covers the flow of products from the retailers to the end customers.

There are, nowadays, several terms of vital importance and debate regarding its influence on sustainable development, such as information technology (IT), information and communication technology (ICT), electronic data interchange (EDI), and Internet. For simplification purposes, to find out where e-commerce lies among this landscape, the above four terms (IT, ICT, EDI and Internet) are presented as follows:

- The term “IT” is included already in a larger term, which is “ICT”. So, (ICT = IT + Telecom). This context includes hardware such as computers, telephones, televisions, cables etc. and the software that run them (Arnfolk, 2002). This is the equipment part of the ICT, while the application part of ICT is for example teleconferencing (both audio-conferencing and video-conferencing), teleworking, etc.
- The Internet is just one form of IT. Whereas the personal computers, cables, softwares, etc. are the equipment of the Internet, the application side (the use) of the Internet comes in many aspects of daily life: chatting, researching, mailing, advertising, trading, presenting oneself, etc.
- E-commerce (trading through Internet) is a phenomenon of the Internet. However, in EDI applications we find also e-commerce. So, e-commerce is also a phenomenon of EDI, which is a type of IT.

A concluding remark for the above is that any study performing assessment of environmental implications of Internet or environmental implications of IT is not considered an assessment of e-commerce alone. Moreover, although e-commerce is just one of the aspects that such an Internet study covers, it does not cover all e-commerce interactions. Studies performing environmental assessment of IT are expected to include all e-commerce

interactions. This is a point of importance as the reader finds different titles of assessments with different term use (IT, ICT, Internet, EDI, e-commerce). In the literature, one can meet several e-prefixed terms (e-business, e-logistics, e-supply chain, e-fulfilment and e-procurement), which are used in the field of supply chain management (SCM). E-business is just another name for e-commerce.

### Methodology

We surveyed the literature in the issue of e-commerce and environment across several fields such as logistics/SCM, the environmental science, and e-commerce/business. This survey searched the volumes/issues of the following journals in the period of 1991-2002:

(1) Logistics/SCM field:

- *European Journal of Operational Research*;
- *Integrated Manufacturing Systems*;
- *International Journal of Environmentally Conscious Design and Manufacturing*;
- *International Journal of Flexible Manufacturing Systems*;
- *International Journal of Logistics Management*;
- *International Journal of Logistics—Research and Applications*;
- *International Journal of Physical Distribution & Logistics Management*;
- *International Journal of Production and Operations Management*;
- *International Journal of Production Economics*;
- *International Journal of Retailing & Distribution Management*;
- *Journal of Business Logistics*;
- *Production and Operations Management*;
- *Supply Chain Management—An International Journal*; and
- *Transportation Research—Part E: Logistics and Transportation Review*.

(2) Environmental science field:

- *Business Strategy and the Environment*;
- *Environmental Impact Assessment Review*;
- *Environmental Science and Technology*;
- *Greener Management International: The Journal of Corporate Environmental Strategy*;
- *International Journal of Life Cycle Assessment*;
- *Journal of Cleaner Production*;

- *Journal of Environmental Management*;
- *Journal of Environmental Planning and Management*;
- *Journal of Industrial Ecology*; and
- *Management of Environmental Quality—An International Journal* (previously *Environmental Management and Health*).

(3) E-commerce/business field:

- *e-Business*;
- *e-Logistics Magazine*; and
- *International Journal of Electronic Commerce*.

For a further reach of literature, we used data triangulation method, i.e. collecting data through different ways. A search by keywords was conducted in some known electronic databases such as: Emerald, Ingenta, and IEEE Xplore (in addition to the World Wide Web). Furthermore, we consulted some authorities/experts. Also, looking up in the reference lists of the already-gathered papers has facilitated a reach to some more papers.

The literature of this topic is fertile of pilot studies and propositions, with very limited support of empirical evidence. Scholars of different backgrounds have studied the impact of e-commerce on the environment differently, in terms of approach, assumptions and demarcations. Table I shows only the studies that made an environmental assessment and presented results. A discussion of these studies follows in the sequel.

Studies	Tools	Demarcations	Concerns	Assumptions
Cairns (1999)	GIS system	Food sector – B2C only	For London City	On routes and distances
Caudill <i>et al.</i> (2001)	LCA tool	Electronic products (desktop PCs as a case) – B2B and B2C	For the USA	(Assumptions for running LCA)
Orremo and Wallin (2000)	Transport emissions	Food sector – B2C only (a case study with a retailer)	For whole Sweden	On population, distances and consumption of fuels
Punakivi and Holmström (2001)	GIS system	Food sector – B2C only	For Helsinki and metropolitan – service concepts	On routes and distances
Luo <i>et al.</i> (2001)	Material flow analysis	Electronic products (desktop PCs as a case) – B2B and B2C	For the USA	Built on stochastic simulation processes
Matthews <i>et al.</i> (2001)	LCA tool	Book retailing in the USA	Different delivery systems in the USA	On distances, types of vehicles and return rate of books (35 per cent)

**Table I.**  
Summary of main  
recent studies regarding  
the environmental  
implications of  
e-commerce

*Use of life cycle assessment*

Matthews *et al.* (2001) have performed a life cycle assessment study for the net effect of environmental implications for book retailing as a case study. They have analysed different delivery systems to assess the environmental and cost impacts. With LCA tool, they have looked at the life cycle of book retailing for both traditional retailing and e-commerce from the publisher to the customer's home, considering the energy consumption and gaseous emissions from different activities: transportation, packaging, production, fuel production, etc. They found that the results of the overall assessment are dramatically influenced by the definition of systems boundaries and input assumptions. One of the assumptions is the return rate for best-selling books, which they set as 35 per cent and make the calculations accordingly. Other two parameters: shipping distances and shopping allocations, are adjusted for their approach and can also be altered to get different results. "By altering these critical parameters, E-commerce can be found to be more or less costly than the traditional system". Nevertheless, their base analysis case suggests that: "E-commerce sales have a cost advantage and environmental benefits". There are some other assumptions made to set the boundary analysis of the LCA tool itself, e.g. all transportation in traditional retailing is carried out by the truck system. The study assumes the type of fuel within the USA. Another limitation is that their LCA model is based upon the US Department of Commerce's 500 × 500 commodity input-output model of the US economy.

Caudill *et al.* (2001) have also performed a life cycle assessment study with a focus on electronic products – desktop personal computers. They have looked at the life cycle stages of this product from: material extraction stage along to usage and then to dumping as waste stage. Some assumptions have been made to specify the LCA boundaries. Their evaluation covers the impact within both B2B and B2C:

The study indicates that just selling products over the Internet in a single B2C practice will result in negative impact on the environment up to 10%, especially if packages are shipped by air express. However, if the full power of web-enabled commerce is implemented, by integrating B2B and B2C, then energy savings and environmental benefits, exceeding 10% improvement over today's business practices, are achievable (Caudill *et al.*, 2001).

They made another study (Luo *et al.*, 2001) using and testing a novel approach, which:

[...] combines fuzzy logic decision theory with a hyper-network formulation of e-business strategies using an integrated physical material flow supply chain structure overlaid with the Internet-based communication network.

They arrives to the conclusion that:

[...] an optimized e-supply chain network for a desktop personal computer product has the potential to yield significantly better performance in terms of business goals and environmental goals than traditional practices".

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*Focus on transport emissions*

Some other studies have focused on the transportation emissions as one way to bring insights about the implications of e-commerce. The limit is set to study the impact in delivering groceries to home-doors, which means three demarcations: within B2C, by transportation impact, for the food sector only. Cairns (1999) has programmed algorithms by TransCAD, which is based on the geographical information system (GIS), for calculating the shortest routes for the City of London. Meanwhile, Punakivi and Holmström (2001) have used the GIS system to study the total traffic for the City of Helsinki and its metropolitan area. Punakivi and Holmström have analysed the transport emissions for several delivery service concepts:

- *Attended* – availability of people at home (with two different “delivery time windows”).
- *Unattended* – reception box (with two different delivery time windows).

According to their simulations, “all the home delivery service concepts are environmentally friendlier compared to the current situation where customers visit the store using their own cars.” (Punakivi and Holmström, 2001). The third study (Orremo and Wallin, 2000) have used a scenario technique to look at the results of emissions from home deliveries compared with those of car shopping by people, and finds a critical distance point where the preference between them changes.

*Focus on other processes – packaging and warehousing*

Some experts have focused on specific subjects such as: the packaging design, or warehousing size and management. The views are different and not in agreement (*Packaging Digest*, 2001). For example, it is suggested that in e-commerce arrangements, we may experience larger numbers of orders with smaller size than experienced in the conventional purchasing system, and this means a new perspective on the packaging issue (Williams, 1999). The optimistic views are searching for the possibilities of increasing the use of re-usable transit packaging through e-commerce. Nevertheless, the subject of warehousing size and management was of interest to experts. Although the expectation is that there will be land use impact by less warehousing space, “the growing need for centralised large warehouses, caused by an increasing trend towards online shopping, might on the other hand lead to increased use of transportation, so that the implications are once again uncertain” (Tuerk, 2001).

*Energy consumption as one viewing angle*

The other literature we found is in fact kind of discussions presenting speculations and expert opinion of anecdotal evidence sometimes. For example, the following arguments are some viewpoints of different researchers (Matthews *et al.*, 2001; Leahy, 2001) taking energy consumption as a basis for assessing the environmental implications of e-commerce.



- Positive impact:

The economy is growing rapidly but energy demand is much lower since the advent of the Internet.

Amazon.com, for example, uses 16 times less energy per square foot to sell a book than a regular store.

Business-to-business e-commerce promises greater energy (conservation) by reducing inventories, overproduction, unnecessary capital purchases and paper transactions.

The Internet can turn buildings into Websites and replace warehouses with supply chain software. Information substitutes for energy.

- Negative impact:

E-commerce is only a fraction of the total economic picture, thus it isn't the reason behind reductions in energy demand. When e-commerce becomes a major part of the economy, what happens to the existing bricks, mortar and asphalt infrastructure of the retail industry?

Estimates of electricity usage alone of operating Internet routers, switches and computers range from 1 percent of total US energy use to an unlikely 8 percent.

Electricity generation is one of the largest national sources of many pollutants.

Huge new warehouses and distribution centers serving e-commerce operations are being built at an incredible pace

And new retail space is still growing despite predictions that people won't visit malls as often.

Reijnders and Hoogeveen (2001) believe that energy use as a topic of discussion might bring different results if taken in a more micro level. They have taken PC distribution as a case study and used some previous data of a Dutch consultancy for their analysis. They mention that there are several issues to consider when it comes to discussing energy use, like: distribution, usage of electricity for PCs, PCs' hazardous waste, and warehousing space requirements. One Conclusion is that there could be gains in energy in the distribution issue, but they found that usage of electricity for PCs (purchasing by the Internet) may far outweighs the energy gain in the distribution. In general, they feel that "as the increased business efficiency that is characteristic of e-commerce in general leads to economic growth one should not be optimistic as to the overall environmental effects of e-commerce".

*Paper consumption as another viewing angle*

Similarly, the consumption of paper has been taken a basis for the assessment. The hope is that e-commerce contributes to less paper resource use when often using digital communication for making orders, sending bills, and so forth (Hurst, 2001), although the experience with "paperless office" story when the personal computers entered the market in early 1980s should serve as a warning:

Even though the digitalisation in many cases have made paper documents redundant, we experiences the opposite trend. We have never used so much paper before in the developed countries (Arnfolk, 2002).

Leahy (2001) edits:

[...] there might be reductions in energy use, but there is a huge increase in packaging and shipping by air (that) results in much more air pollution. Office paper use has doubled since the widespread use of computers - so much for the promise of the paperless office.

Hurst (2001) questions “how many of us print up e-mail correspondences or a long list of product information from retail Websites?”:

Companies aim to capture customers using a combination of shops, catalogues and the Internet. Paper catalogues are far from disappearing!

### *Classifying the environmental effects*

Tuerk (2001) and Fichter (2001) adopt a comparable classification for the type of environmental effects of Internet and e-business (see Table II):

- (1) *Primary effects*: IT infrastructure.
- (2) *Secondary effects*: application.
- (3) *Tertiary effects*: consumption patterns and rebound effects.

This classification is by no means meant to be a rank of importance. Tuerk (2001) emphasises:

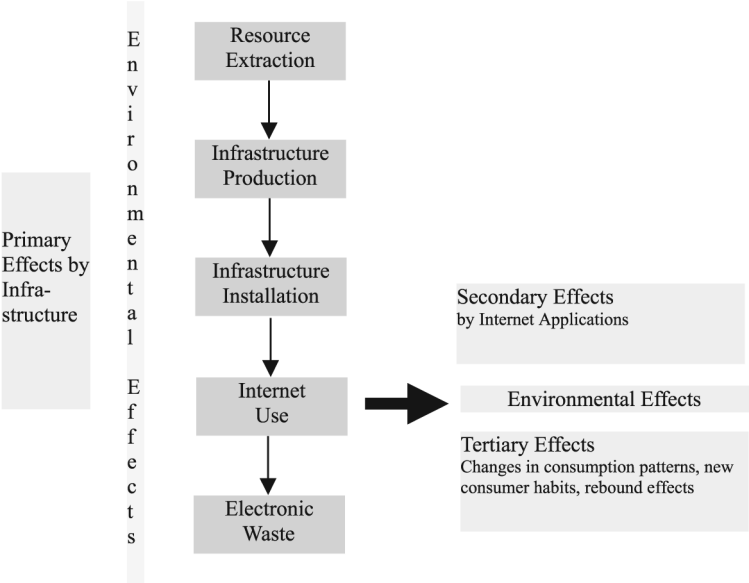
[...] despite the fact the primary effects might have a considerable impact on the environment, secondary and tertiary effects most likely are equally important or outweigh them in their relevance.

In an interim report of Digital Future project of the European Community (2002), a similar classification is adopted but from a life cycle perspective (see Figure 1).

Effect	Caused by	Examples	Aspects
Primary effects	Infrastructure	Terminal equipment such as the PC, mobile phones Network infrastructure Servers, routers, etc.	Energy consumption Material consumption Toxicity of end-of-life equipment
Secondary effects	Application	B2B Change in warehousing Change in transportation Change in packaging	Energy consumption Material consumption Traffic Land use
Tertiary effects	Changes in consumption pattern, new habits, rebound effects	Increase in consumption Substitution effects Side effects	Energy consumption Material consumption Traffic Land use

**Table II.**  
Classification of the  
environmental effects of  
Internet

**Source:** Tuerk (2001) – adapted with little modification



**Figure 1.**  
A life cycle classification  
of the environmental  
effects of the Internet

Source: Digital Future (2002)

*Overall view*

In general, among several pilot studies and reports, we find a common view for the researchers that “there is no general answer to the question whether e-business and Internet use entail increased or decreased environmental impacts. Up to now, there are examples of both environment-friendly and environment-damaging effects” (Fichter, 2001). Similarly, a concluding statement in a symposium at the New York Academy of Science on e-commerce and environment reveals that “without a crystal ball it is impossible to say what kind of impact the Internet and wireless communication will have on the environment” (New York Academy of Sciences, 2001).

To complement our review of the literature, we should mention that we found some studies that made LCA assessments for the environmental implications of the Internet infrastructure (using process LCA and input-output LCA) (Loerincik *et al.*, 2002). Another study (Tuerk, 2001), also focusing on the Internet infrastructure, used another approach for the assessment: Material-flow oriented approach, looking at the resource consumption of products or services through their material intensity. This approach is in fact a sister of LCA method.

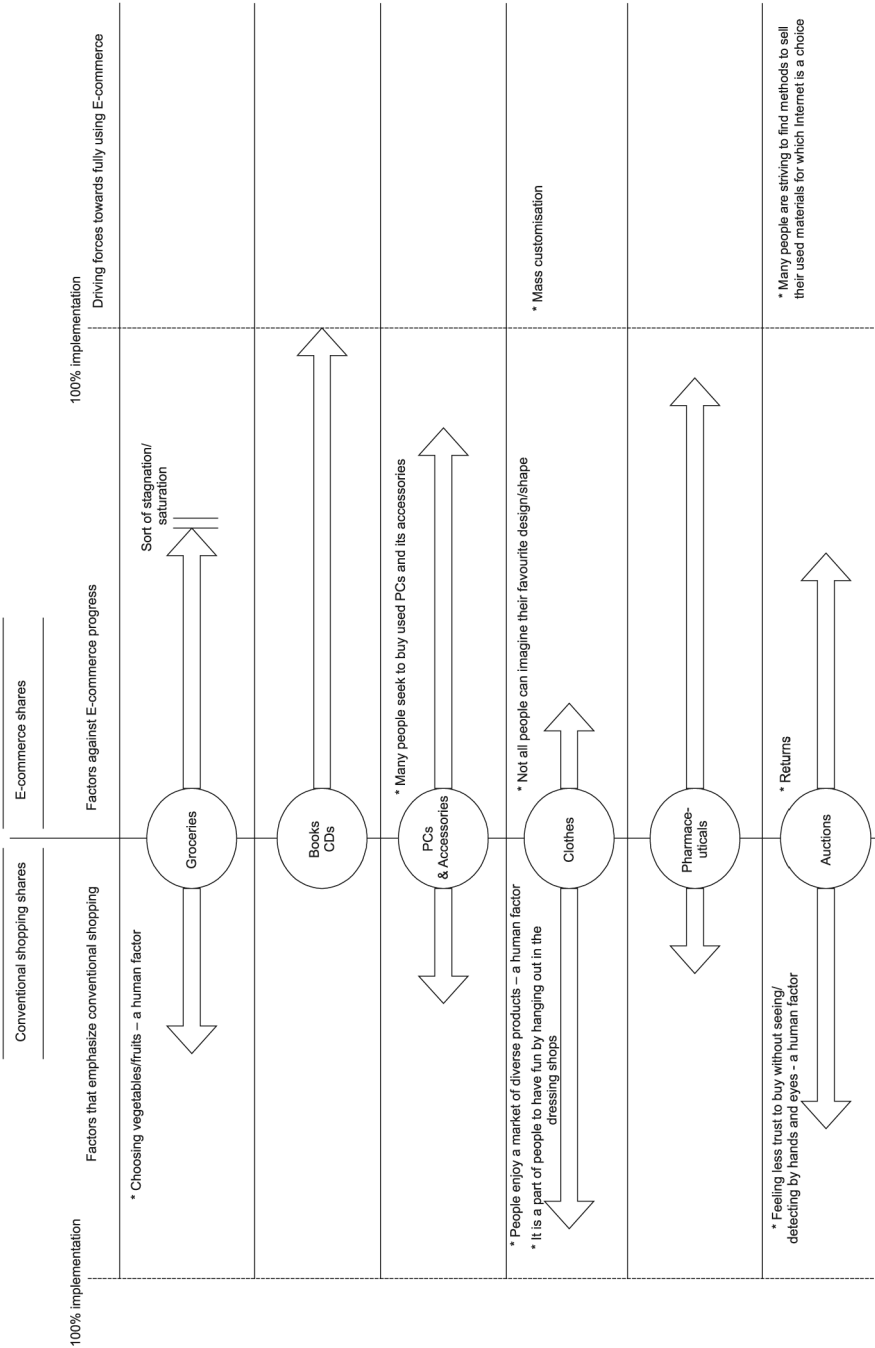
**Discussion**

By analysing the previous literature, we find that e-commerce has the following several dimensions:

- *Trade type.* There are several types of merchandise (grocery, pharmaceuticals, books, etc.).
- *Product focus.* This can be on one product type in a specific merchandise, or it can focus on all the types available in this merchandise, and the focus can be zoomed more on one article of a product type, or all articles of this type of product of a merchandise.
- *Geographical borders.* There are different geographical levels (city, county, state, continent, global).
- *Supply chain spectrums.* There are two spectrums: B2C and B2B.
- *Penetration into market.* With e-commerce, the different merchandise might penetrate the market differently and probably not in the same way, due to several reasons including human psychological factors (Li, 2000). For example, e-commerce might highly succeed in the books merchandise, while for the vegetables it might be less successful (refer to the speculating scenario of Figure 2).
- *Impact dimension:* The impact of e-commerce touches several aspects of life such as people transportation, goods distribution, packaging design, warehousing etc.
- *Tools/resource dimension.* We may tackle e-commerce using a specific tool like, for example, GIS, or focusing on the use of a specific resource, e.g. energy use, paper use (or rather more general: materials consumption) etc.

Based on these dimensions, we would have a considerable number of choices/combinations. For example, we may choose to study e-commerce for food trade in Stockholm city within B2C, and we may choose to set a different boundary for the assessment, for example, E-commerce for groceries, books and pharmaceuticals in Sweden along the whole supply chain; B2B and B2C. So, such a breadth of choices must be specified, as this will influence the shape and amount of impact assessment results. Figure 3 gives some feeling for the reader about the number of combinations we may have if we perform such assessments. Furthermore, this diagram includes only the situation where we are supposed to use a specific tool like GIS or LCA, while there could be other approaches by analysing resource use: paper use, energy use, or materials use (some examples have been introduced in the “Literature” section).

For the other component of our topic (i.e. the assessment method), we have to consider the available methods for this purpose. Generally, e-commerce is a topic of concern for several disciplines such as computer science, management, production, logistics, packaging, business science, etc. One acceptable angle to look at e-commerce from, for environmental purposes, is the SCM discipline for two main reasons:



**Figure 2.**  
Example on different expectations for B2C e-commerce among some selected merchandise

	Groceries			Publications (including books/CDs)			Pharmaceuticals			Electronics			Clothes			Second Hand			No Specific Merchandise (In general)
	B	B2C only	Whole supply chain	B2B only	B2C only	Whole supply chain	B2B only	B2C only	Whole supply chain	B2B only	B2C only	Whole supply chain	B2B only	B2C only	Whole supply chain	B2B only	B2C only	Whole supply chain	
General	Overall impact on different facets (transport, packaging, production, warehousing, etc.)					LCA – (in the USA)						LCA – (in the USA)							
Focused	Transport		(1) GIS (London city)																
			(2) GIS (Helsinki city)																
			(3) Gaseous emission scenario (Sweden)																
	Warehousing																		GIS – (in the USA)

Environmental  
implications of  
e-commerce

**Figure 3.**  
Diagram of several  
dimensions for assessing  
the environmental  
implications of  
e-commerce

- (1) In SCM discipline, we find several engineering disciplines interacting (mainly: production, packaging, warehousing, and transportation).
- (2) SCM crosses the life cycle of the products from the raw materials provision to manufacturing site all through to the stage of use of products by the consumers. This is the typical path for the environmental life cycle assessment.

Abukhader and Jönson (2002a) found that LCA is the widely used method of doing an environmental assessment in this regard, and is the method that is often used in the subject of SCM and environment. This method helps to conduct a product-specific assessment within the framework of comparing the product of concern with other products in the market by looking at the total life cycle from: production to disposal (Jönson, 1996). In this sense, this method has a specific capacity, and in case of use for e-commerce issue, then the assessment has to focus on a specific product in a specific country boundary, providing that the LCA assessment gives a comparative insight for the product of concern itself with no summation figures for the total millions of items produced by this product. This is in addition to making some necessary assumptions to jump over the obstacles of collecting sufficient, rather large amounts of data. Therefore, LCA can be used, but in a limited capacity.

#### *Framework for future investigation*

According to the “map” in Figure 3, a question is raised: “Should we continue to fill the table blocks by similarly conducting separate LCA studies, or should we consider another approach for this research issue?”. Considering the following observations, some ideas are suggested afterwards:

- Contradictory results in previous studies.
- Opposite results when setting the boundary of assessment to B2C only than setting the boundary to B2B and B2C together (as in Caudill *et al.* (2001)).
- Missing the impacts in some other different places. (In such a very large urban detailed system we are dealing with, as can be felt from Figure 3, there is no guarantee that an impact that happens at a point somewhere in this large picture gets compensated at another point somewhere else.)

First, while referring to Table II, we notice that the primary effects are shared among several applications of Internet (and information technology) not only e-commerce. Hence, it is rather difficult to evaluate these effects for e-commerce separately. In the meantime, the tertiary effects are in fact a social science issue in the first stand. Therefore, the secondary effects are currently the possible focus for evaluating the environmental implications of e-commerce.

Second, Abukhader and Jönson (Abukhader and Jönson, 2002b, Abukhader, 2003) propose ideas and initiatives for new direction of environmental

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assessment. These studies are in fact based on an idea that we should look for something else than the current traditional way of assessment. The current method of performing environmental assessment for the implications of e-commerce is of low importance. Behind this belief, there are three points of consideration:

- (1) We have a mix of technology and unpredictable human behaviour that makes the shape of life in the future highly unpredictable and accordingly impossible to base a comparison on. One example for this is the paperless office vision mentioned earlier.
- (2) The assessment boundary set to assess the environmental implications will stay micro and will be able to neither consider effects compensated in different points in the large picture of the system, nor consider rebound effects.
- (3) There are several issues moving in parallel in the current time such as building sustainable transportation system (enhancing railway, more use of electric/hybrid cars, better engine performance, highly efficient catalytic converters, etc.). So, comparing, for example, two choices of: (people driving to supermarkets (vs.) white vans sending orders to home-doors) will not be of high value if the future witnesses a switch into electric cars and electric vans.

The proposition here is that instead of looking at e-commerce as “a vehicle driving towards freely satisfying the market needs, we should look at E-commerce as “a cart attached to our vehicle towards sustainable development”. The helping factor is that we are still in the early stage of having e-commerce as a potential effective trading channel. Another point, why this proposition is more important than the assessment, is that e-commerce, as explained earlier, is a phenomenon of Internet, which is spreading all over the globe inevitably. In brief, we need to “design the end” and work towards that “end” instead of keep things move freely to unknown future and stay assessing and comparing with “this” unknown. Yet, Abukhader and Jönson (2002b) extend the proposition with a suggestion for the assessment concern. To gain a more realistic picture, we should adopt performing a two-dimensional environmental assessment – vertical and horizontal assessments, instead of performing the traditional one-dimensional environmental assessment.

### **Concluding remarks**

The literature to date contains a great deal of pilot studies, interim reports and anecdotal arguments, speculations, and limited number of LCA assessments for e-commerce, for Internet and for more generally ICT. The main observation is that there are difficulties to bring empirical evidence and difficulties to generalise the results. Some reports find negative impacts for e-commerce, and some find positive impacts, however most of the studies indicate that there are



both advantageous and damaging effects to the environment. There is a general agreement that it is highly difficult, if not impossible, to state if the environmental negative effects of e-commerce can weigh over the positive effects or the contrary.

One proposition in this context is that we should look for something else than the current traditional way of assessment when it comes to e-commerce. The idea is that instead of looking at e-commerce as “a vehicle driving towards freely satisfying the market needs, we should look at e-commerce as “a cart attached to our vehicle towards sustainable development”.

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# PAPER 2

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## E-commerce and the environment: A gateway to the renewal of greening supply chains

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**Abstract:** Electronic commerce is expected to influence a wide range of supply chain systems and thus lead to unidentified environmental impacts. Current studies discussing the impacts have the problem common in that they arrive either at conflicting or un-generalisable results. This article addresses the issue of methodology and proposes an assessment model for the resolution of this problem. Some important implications of this novel model for supply chain management are presented. This article shows that the subject of “Greening supply chains” is in need of a new focus and direction in research which involves building a new set of constructs for decision-making. Several benefits of this are addressed. Research in this subject is somewhat stagnating nowadays; it lacks specific research themes that are necessary for the integration of the available knowledge. Our model, proposed in this paper, represents a meeting point of the need of renewal of this subject, and the need to evaluate large-scale issues such as electronic commerce.

**Keywords:** electronic commerce, environmental assessment, greening supply chains, life cycle assessment, horizontal assessment, Internet, information technology, Just-In-Time, postponement in supply chains

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## 1 Introduction

Discussing the topic of environmental consequences of electronic commerce (E-commerce) will concern several research areas, including the area of the subject of “Greening supply chains”. In this topic, three perspectives are involved: E-commerce, Logistics/Supply chain management (SCM), and Environmental science. For the environmental science side, E-commerce is just a business concept and cannot be evaluated as is. But, it is possible to evaluate it by assessing the influence it has on the processes of supply chains. In brief, an environmental assessor will be interested in looking at the changes arising in supply chains when using E-commerce.

Is this of any importance? E-commerce is expected to influence a wide range of man-made systems of the industrial infrastructure, including systems of manufacturing/production, transportation, packaging, warehousing, etc. Moreover, E-commerce is at the very departure to be an effective trading channel. That is why this chance should be invested in environmental investigations before the environmental abatement measures become difficult to implement in the future. The impact is as yet of unknown extent and will arise in uncertain ways.

In addition, the topic of environmental assessment (in general) is of importance to the development of the logistics/SCM discipline. In general, the subject of “Logistics/SCM and Environment” should have two lines of discussion: the assessment, and the measure implementation. The assessment discussion develops through the availability of two themes: “*assessing the impact of logistics on the environment*” and “*assessing the impact of the environment on logistics*” [1]. In [1], the authors demonstrate that the logistics/SCM-related journals have considered only the second theme and did not treat the first. In addition, based on a content analysis work, they show that in fact these journals have treated the subject concerned notably less than any other subject established in the field. These results have led to the question as to whether it can even be considered an established subject. These two themes of assessment are complementary and feed into each other continuously; missing one of them weakens the development of this knowledge. This is one reason why research in greening supply chains is somewhat stagnating.

The literature to date on the environmental implications of E-commerce indicates a limited knowledge. The total literature is primarily in the form of pilot studies, anecdotal arguments, and a limited number of life cycle assessments, with the problem common in that the results are either conflicting or un-generalisable [2].

### 1.1 Purpose

The purpose of this paper has been to shed light on this problem in relation to the assessment methods used, and within this frame, we propose a novel assessment model that builds on and expands the current, commonly used method. As a consequence, an important objective has been to show that the topic of “E-commerce and the Environment” contributes immediately to the knowledge of “Logistics/SCM and the Environment”, as one implication of the proposed model. Ultimately, the aim has been to focus attention on the fact that, in order to further develop this model, requires that a new set of constructs for decision-making in “Logistics/SCM and Environment” be developed.

## 2 Methodology

This paper is based on an extensive survey across several disciplines, such as logistics/SCM, environmental science, manufacturing, production, and operations management. This survey sought several topics in interdisciplinary environmental knowledge. The aim has been supporting a work on concept development for the sake of proposing an assessment model to resolve the problem of conflicting results/un-generalisability. The second purpose of this survey task was to serve as the source of evidence (input) for the carry out of this assessment, due to the nature of the model structure, which will be described later.

This survey was conducted by looking at each issue/volume of 29 selected journals published over a period of ten years (1992-2001). The criteria for selecting journals are: being primary journals and



having SCM as one of its themes. Probably some other journals could have been included; however, we assumed that the following list to have a reasonable coverage of the knowledge we needed:

**Logistics/SCM-related journals:**

1. *International Journal of Logistics – Research and Applications*
2. *International Journal of Physical Distribution and Logistics Management*
3. *Journal of Business Logistics*
4. *Supply Chain Management – An International Journal*
5. *The European Journal of Purchasing and Supply Management*
6. *The International Journal of Logistics Management*
7. *The Journal of Supply Chain Management* (before 1999 called: *International Journal of Purchasing and Materials Management*)
8. *Transportation Journal*

**Environmental Science-related journals:**

1. *Business Strategy and the Environment*
2. *Environmental Impact Assessment Review*
3. *Greener Management International: The Journal of Corporate Environmental Strategy*
4. *International Journal of Life Cycle Assessment*
5. *Journal of Cleaner Production*
6. *Journal of Industrial Ecology*

**Journals related to other disciplines:**

1. *British Journal of Management*
2. *California Management Review*
3. *European Journal of Operational Research*
4. *Integrated Manufacturing Systems*
5. *Interfaces*
6. *International Journal of Environmentally Conscious Design and Manufacturing*
7. *International Journal of Flexible Manufacturing Systems*
8. *International Journal of Production and Operations Management*
9. *International Journal of Production Economics*
10. *International Journal of Retailing and Distribution Management*
11. *International Journal of Technology Management*
12. *Journal of Operations Management*
13. *Production and Operations Management*
14. *Technological Forecasting and Social Change*
15. *Transportation Research – Part E: Logistics and Transportation Review*

Regarding the application/empirical side of the model, the results of the survey, which is supposed to be the source of evidence into the model, have led to some limitations; the evidence needed is very limited. (This limitation, as a by-product of the work, has led to discover a significant gap in some types of environmental knowledge for SCM; further discussion is presented later.) However, based on the available evidence, we present two tentative examples of how a change from one strategy of supply chains to another can be looked at from an environmental point of view. The two examples are:

- a. Adopting the Just-In-Time strategy, and
- b. Changing from one type of postponement strategy to another.

The Delphi method, for instance, could have been utilised as an alternative to the survey; however, some limitations in our project did not permit such an experiment. More discussion on the model, type of evidence, and the two examples will be provided.

### **3 Evaluating E-commerce**

This section presents a supporting background before proposing the novel model and then the two examples. The section concludes with a discussion on the empirical side of the model and directions for future considerations.

#### **3.1 Background**

##### *E-commerce*

Several definitions of E-commerce can be found. One definition is: “any form of business transaction in which the parties interact electronically rather than by physical exchanges or direct physical

contact” [3]. Another, similar definition is: “a critical component of supply chain management that includes the conduct of any business transaction using digital rather than physical means” [4].

Generally, when studying E-commerce, several demarcations have to be specified such as: the merchandise type, geographical borders, supply chains spectrum either B2C or B2B or both, the market share as a competing trading channel, etc. Several factors [5], such as cost, human factors, access to Internet, etc., will differently determine this market share according to the type of merchandise/product. One more demarcation is the impact form, which comes basically in three forms: primary (infrastructure effect), secondary (application effect) and tertiary (rebound effects) [6, 7, 8] (Table 1). This classification does not indicate any type of ranking or preference; it is only a sort of categorisation. At the end, as can be realised that the total demarcations will form several combinations of studying levels – “magnification levels”.

### *Environmental Assessment Methods*

Among several methods, the most commonly used for assessing the impacts on the environment is, generally, the Life Cycle Assessment (LCA) [9]. It is an internationally standardised method and is mentioned within the frame of ISO14000 International Environmental Standards [10]. Similarly, there is a clear dominancy in the literature on “Logistics/SCM and the Environment” to utilize LCA [1]. Behind this might be several reasons. An important one is that LCA has a similar principle of SCM in having a holistic view over the chain of processes/stages that the products pass through: from raw material extraction to manufacturing, distribution, and use until disposal [10].

### *E-commerce & the Environment*

Consequently, there is a clear tendency to use LCA as the favoured method by which to discuss the environmental effects of E-commerce. In spite of the fact that LCA is normally conducted for a specific product across a supply chain; however, it was used here to evaluate a technology, namely, E-commerce.

**Table 1** Classification of the environmental effects of E-commerce ([6] – adapted with minor modifications)

Effect	Caused by	Examples	Aspects
Primary effects	Infrastructure	Terminal equipment such as the PC, mobile phones	Energy consumption
		Network infrastructure	Material consumption
		Servers, Routers etc	Toxicity of end-of-life equipment
Secondary effects	Application	B2B	Energy consumption
		- Change in warehousing	Material consumption
		- Change in transportation	Traffic
		- Change in packaging	Land use
		B2C	
Tertiary effects	Changes in consumption pattern, new habits, rebound effects	Increase in consumption	Energy consumption
		Substitution effects	Material consumption
		Side effects	Traffic
			Land use

### *Demarcations*

One demarcation for our research work is that its concern is only for E-commerce and not for IT (information technology) or Internet. Readers often meet several different terms for instance IT, ICT (Information and communication technology), Internet, EDI (Electronic data interchange), and E-commerce. E-commerce is one activity among several services (emailing, chatting, presenting oneself, researching, etc.) provided by the Internet, which is one type of IT. We are concerned with evaluating E-commerce only, not evaluating Internet with all its activities.

A second demarcation is the focus on the secondary effects, i.e. those effects of the use/application of E-commerce infrastructure (Table 1). Whereas the primary effects are concerned, to a limited extent, with the waste of electronic equipment at the end of their life, the secondary effects are of a higher complexity and interacting events. The tertiary rebound effects are important, but they are more likely to represent human behaviour.

### *3.2 A Proposed Model of Assessment*

The purpose of the forthcoming discussion is to build the reasoning for the problem behind using LCA. This results in a novel model of assessment that expands the capacity of LCA, not in its regular form, but in a cross-disciplinary supply chain management language framework. The model will be based on two pillars as presented next.

#### *The First Pillar*

The first pillar is the holistic assumption that is found in the Systems Approach school [11]: If an impact, in some form and amount, occurs at a point somewhere in a system, this impact might be compensated for at another point somewhere else in a similar or different form or amount (for the convenience of the paper, we would call this assumption “impact compensation”). Several arguments in the literature reflect this view, as follows:

For example, “a switch to the use of a material that is more readily recycled may seem like an environmental improvement on the face of it. However, such a change may introduce different production processes upstream in the supply chain, perhaps, for example, releasing larger amounts of ozone-depleting gases than was previously the case. Such contingent effects need to be taken into account” [12]. Another example is when switching to a strategy like Just-In-Time (JIT). This may seem like an environmental improvement, as it contributes to reducing the size of warehousing, but “JIT usually requires the supply of materials in smaller lot sizes with more frequent deliveries. This may cause greater transportation and packaging-related environmental problems” [13]. Some further arguments can be found also in the production/manufacturing field. Some critics point out “that reducing one factor of production may increase another. Efforts to increase the efficiency of throughputs may lead to a greater production of waste. Reducing inventory, for example, may lead to a greater production of waste. The small batch size production inherent in lean production entails more frequent changeovers, and these changeovers might require cleaning of production equipment and disposal of unused process material” [14]. Also in the logistics field, it looks that “the nature of logistics management is cross functional and integrative and since so many logistical activities impact on environment,” and therefore “to minimise total environmental impact, it must be evaluated from the total system perspective” [15].

#### *The Second Pillar*

The second pillar is based on the idea that E-commerce should not be regarded as a pool of products, but as one of three components in man-made systems: the process that produced the output, the technology used to execute the process, and the decisions/strategies that control the forms, conditions and location of the process. As these systems are un-natural and need to be assessed and monitored, consequently the assessment should be performed around three central axes:

1. The Process/Product axis,
2. The Decisions/Strategies axis, and
3. The Technology axis.

Matching these axes as a basic conceptual structure to a supply chain, and drawing horizontal lines to represent four main physical processes [16]: Production/Manufacturing, Packaging, Transportation, and Warehousing (a non-physical process can be, for example, inventory management or order processing), we accordingly parallelise the previous three axes of assessment as follows:

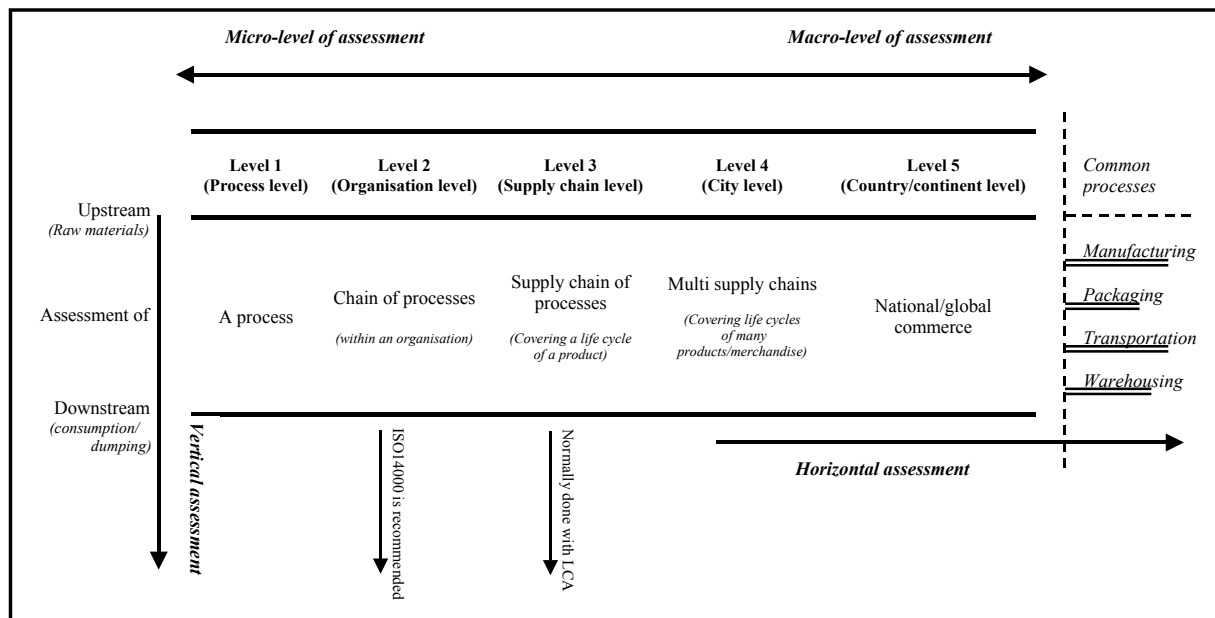
1. Process/Product [vertical assessment],
2. Decisions/Strategies [horizontal assessment], and
3. Technology [full-scale assessment = vertical + horizontal assessments].

### *The Whole Picture*

The model is diagrammed in Figure 1. We suggest that there are five distinct levels for performing an environmental assessment. Whereas level 2, for example, is considered a “micro” assessment, level 4 is relatively “macro”, because the assessment has a “broader perspective” in the latter level. In other words, the system boundary is relatively larger for level 4 than level 2. One clarifying example of how sensitive this point is an LCA study assessing E-commerce [17]. This study got negative figures for the total impact when the boundary was set to B2C only, and contrary positive figures when the boundary was set to B2B and B2C together.

Therefore, a full-scale (i.e. both vertical and horizontal) assessment would allow us to gain a more realistic picture of the situation in E-commerce. The vertical might be performed in level 3 (by LCA), but it should preferably be in 4 or 5, although these latter would encounter a difficult obstacle concerning data collection and quality; sometimes it might even be impossible to handle. This is because when the study boundary becomes as large as a region or state or global, a considerable number of assumptions will have to be made, complicating as a consequence the process of collecting emission data. While the agenda of researchers nowadays, by the use of LCA, is in fact considering performing vertical assessments only, the horizontal work (the missing axis) is our focus in the next section.

**Figure 1** The levels and axes of environmental assessment



### 3.3 Towards Developing Horizontal Environmental Assessment

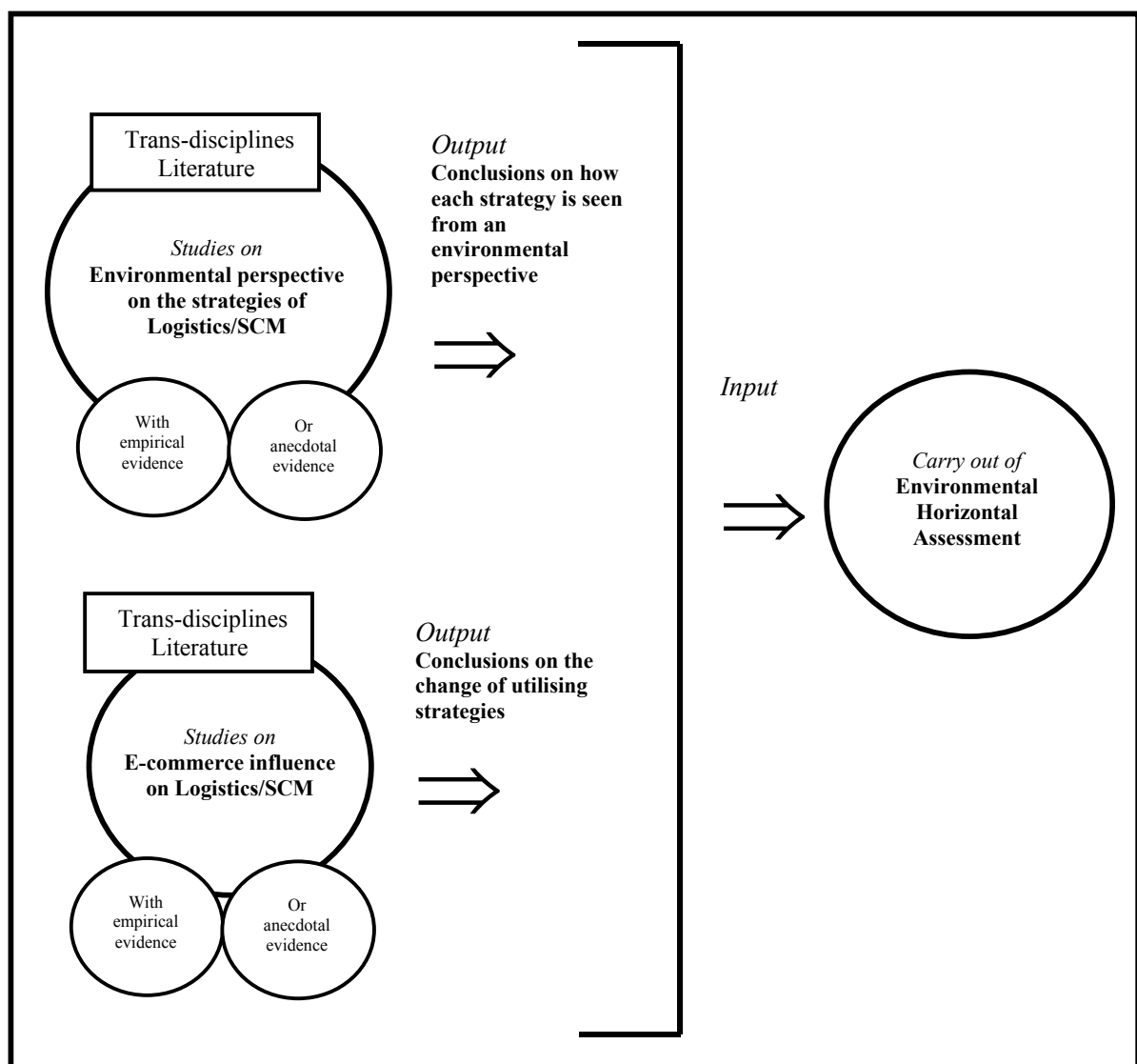
#### Data and Application

The source of data (evidence) as an input to the model is the trans-disciplines literature, because the types of evidence needed are basically two (refer to Figure 2):

1. The conclusions drawn on how the SCM strategies are seen from an environmental perspective, and
2. The conclusions drawn on what virtual changes will take place in utilising SCM strategies (from one strategy to another) due to the object of assessment (in our case it is E-commerce).

There are many strategies, such as Just-In-Time, postponement (of different forms), decentralisation, centralisation, differentiation, standardisation, customisation, etc. So, the conduct of the horizontal assessment is to judge/evaluate the change in strategies by E-commerce from an environmental perspective.

**Figure 2** Types and source of evidence necessary for input to the horizontal assessment; E-commerce as an example



### *Example 1 – Adopting Just-In-Time Strategy*

This example is about evaluating the adoption of Just-In-Time strategy. Several driving forces, including E-commerce, can be behind accelerating this change.

#### *– Step One: Collecting evidence*

The available evidence found through our survey is summarised in Figure 3 (appendix).

#### *– Step Two: Conducting an environmental evaluation*

One way to conduct an environmental evaluation can be as in the following text:

The opinions, on the environmental advantages and disadvantages of Just-In-Time, can be classified into two main streams:

1. Proponents of JIT believe that JIT will result in *lower levels of waste*, associated mainly with reducing levels of inventory; meanwhile,
2. Other scholars find that JIT leads to *congestion and inferior types of transportation* (The “inferior types of transportation” term is clarified by looking at one type of hierarchy, ranking transportation modes from an environmental perspective – Figure 4).

In total, from an environmental point of view, JIT appears more optimistic than pessimistic. Although there are critics which contend that reducing levels of inventory may adversely lead to a greater production of waste and more frequent changeovers, the first stream emphasises that when adopting quality standards there is good evidence that reducing levels of inventory leads to lower emissions of chemicals. On the other hand, despite the available empirical and anecdotal evidence on the environmental disadvantages, some scholars believe that the use of combined transport options is a window of opportunity to alleviate the negative impacts. In addition, there is good evidence of some benefits from JIT: supporting pollution prevention/source reduction plans, and reducing set-up times in manufacturing.

### *Example 2 – The Change in Postponement Strategy*

This example is about evaluating the change from one type of postponement to another. There are four main types of postponement as summarised in Figure 5 [20, 21, 22]. Several driving forces, including E-commerce, can be behind accelerating changes in postponement forms.

#### *– Step One: Collecting evidence*

The available evidence found through our survey is summarised in Figure 6 (appendix).

#### *– Step Two: Conducting an environmental evaluation*

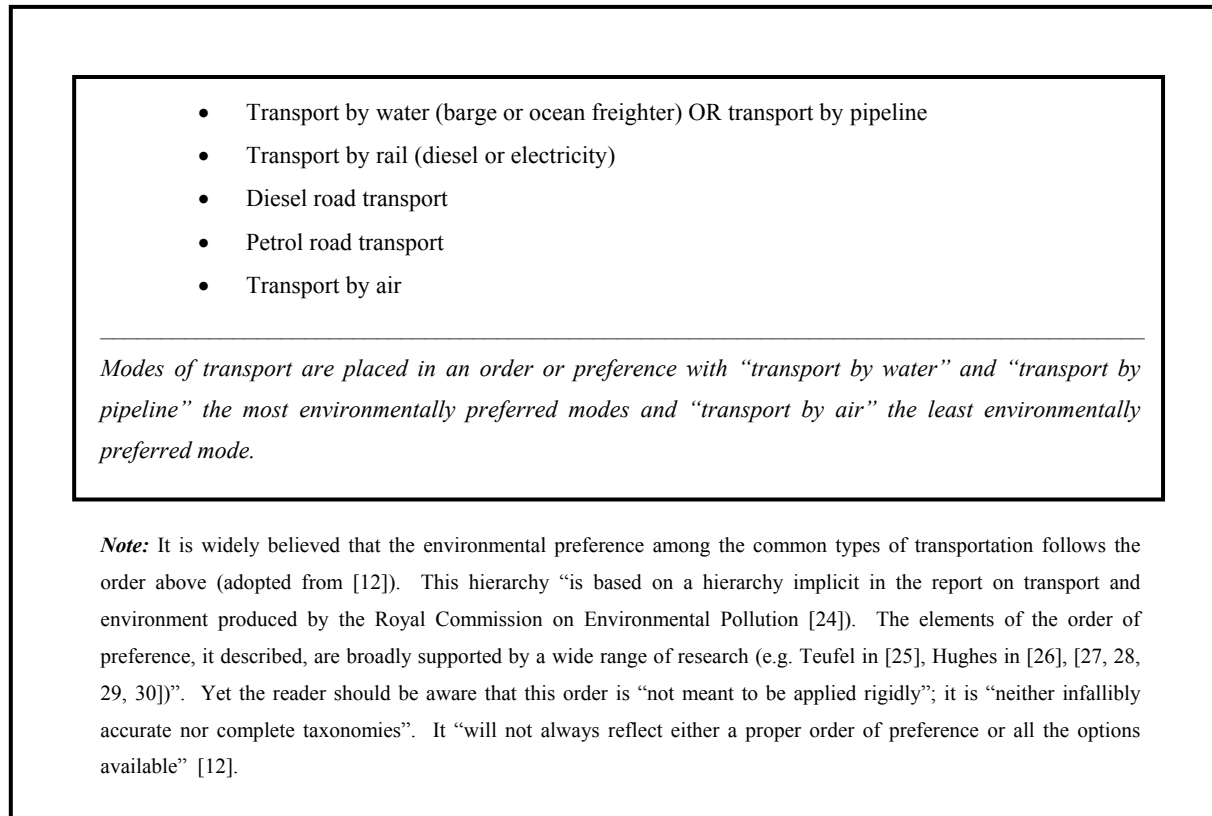
One possible plan for conducting this evaluation is presented in Figure 6 (appendix). The idea is to simulate a SWOT analysis, but will be referred to as: “environmental SWOT analysis;” nevertheless, there might be other possible plans/procedures. Worth mentioning here is that a similar tool has been used for the topics of “corporate business and environment”, recommended for improving corporate environmental policy [23]. But, the difference is in substituting the usual words “Strengths” and “Weaknesses” by “Advantages” and “Disadvantages”, in order to avoid misleading judgments.

The main benefit of this way of doing the analysis is to see the fishbone tree of cause and effect, and see where the black spots lie: Is it more about transportation effects that lie in one or another strategy? Is it mostly effects of production processes that dominate at one or another point? For weighting the advantages and disadvantages against each other, this must be applied at a country/regional level. Although one criticism points immediately to the difficulty of how to weight, for example, “less land use impact” with “higher setup of a manufacturing process,” a scale or a ranking system can be developed according to the conditions of a country/region. Unfortunately, this work is beyond the scope of this paper and has been left for future research.

Another critique is that it is not easy to generalise and state that a specific type of postponement will dominate the market. In addition, it is difficult to predict the type of shift E-commerce will lead to specifically. It might happen that a mix type of postponement strategies take place in the market, although some scholars [21] believe that “catalogue sales and E-commerce (...) employ a logistics postponement strategy”. This is in the sense that “there have been a number of industry-wide initiatives in recent years to postpone logistics. Just-In-Time shipping, Efficient Consumer Response,

Quick Response and Supply Chain Management strategies have all shortened the supply chain (except when the strategy's only effect was to push inventory carrying costs onto suppliers)".

**Figure 4** A hierarchy adopted from [12]



**Figure 5** Supply chain implications of postponement strategies [20, 21, 22]

<p>1. <i>Full speculation:</i></p> <ul style="list-style-type: none"> <li>• Mass production and economy of scale</li> <li>• Decentralised warehousing, shipping in truckload quantities</li> <li>• High cost of inventory, low cost of production and distribution</li> </ul>	<p>2. <i>Logistics postponement:</i></p> <ul style="list-style-type: none"> <li>• Centralised warehousing</li> <li>• Cross-docking mostly, and using automatic identification</li> <li>• Standardised packaging</li> <li>• Shorter supply chain and shipping only to order</li> </ul>
<p>3. <i>Manufacturing/packaging postponement:</i></p> <ul style="list-style-type: none"> <li>• Decentralised warehousing</li> <li>• Semi-finished products, final differentiating steps at decentralised point</li> <li>• Light final manufacturing and labelling/packaging when orders are requested</li> <li>• Ex: colouring paints products, and vehicle customisation</li> </ul>	<p>4. <i>Full postponement:</i></p> <ul style="list-style-type: none"> <li>• Centralised warehousing</li> <li>• Delaying final process to produce customised product</li> <li>• Do all (produce, pack and ship) when orders of customers are received</li> <li>• Low cost of inventory, high cost of production and distribution</li> </ul>

## 4 Conclusions and Implications

Our research shows that the subject of “Greening supply chains” is in need of a new focus and direction in research. Such a new direction should involve building new constructs for decision-making, by performing environmental assessments of the different known-to-date supply chain strategies such as: Just-In-Time, postponement, customisation, modularisation, centralisation, decentralisation, differentiation, standardisation, to mention only a few. This need is emphasised through a number of its rewarding benefits. The first benefit is the potential to activate this subject, which at present appears stagnating. A second benefit is helping in carrying out complex environmental assessment for large-scale issues such as E-commerce. Our proposed model in this paper is another helping contribution to this complex assessment. Using Life Cycle Assessment alone is not an appropriate methodology; our proposed, two-dimensional model is the proper approach to gain a more realistic picture.

A third benefit is the potential to build the missing theme (in the Logistics/SCM-related journals): “*assessing the impact of logistics on the environment*,” but in a framework of language and terminology that suits the logistics/SCM discipline. This theme complements the other theme: “*assessing the impact of the environment on logistics*,” which in fact represents what is nowadays known as “Greening supply chains”. The two themes together, feeding into each other and forming a more complete picture, would represent knowledge for, instead, a larger umbrella: “Logistics/SCM and the Environment”. Our proposed model for assessing E-commerce contributes in this regard by its structure (vertical and horizontal assessments) and by connecting environmental concepts such as the Life Cycle Assessment with logistics concepts such as postponement in supply chains and other miscellaneous strategies of supply chains.

Adopting these ideas and developing the proposed model of this paper in the future agendas of logisticians will be an interesting gateway to the renewal of environmental issues of logistics/SCM. One more benefit why logisticians should take an effective role in this type of assessment (“*assessing the impact of logistics on the environment*”) is that today many papers on environmental science regard logistics as merely a “transport activity”. A logistician with environmental assessment interests can bring a better understanding to this field than an environmental scientist with insufficient background in the logistics/SCM discipline.

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## Appendix

**Figure 3** The evidence collected for the Just-In-Time example

<p style="text-align: center;"><i>“Environmental Advantages” of JIT</i></p> <hr/> <p>King and Lenox [14], in their review, state that “the ‘good housekeeping’ practices associated with lean production have the subsidiary benefit of reducing spills and other forms of waste. Hence, scholars propose that the adoption of lean production practices will improve the environmental performance of manufacturing establishments”. King and Lenox [14] find “strong evidence that establishments that minimize inventory and adopt quality standards are more likely to have lower emissions of toxic chemicals, and these facilities reduce emissions through pollution prevention rather than end-of-pipe treatment of waste”. They propose that “lean production is complementary to environmental performance” and that “adoption of lean production may lower the marginal cost of pollution prevention,” showing that “lean production is associated with greater source reduction (pollution prevention)”.</p> <p>Klassen [31] “observed links between investment in JIT and improved environmental performance”. He finds that “increasing the allocation of investment in environmental initiatives to pollution prevention, instead of pollution control or management systems, improved delivery performance”. This study emphasises though that “when implementing JIT, production managers should try to also capture elements of pollution prevention” and “yet, joint implementation of JIT manufacturing and pollution prevention is an important step toward more sustainable manufacturing practices today”. In addition, by referring to Lawrence and Hottenstein [32], Klassen states that “typically, JIT includes reducing setup times in manufacturing and developing supplier partnerships. Successful implementation should reduce lead times and inventory levels, and improve customer service”.</p> <hr/> <p style="text-align: center;"><i>“Environmental Disadvantages” of JIT</i></p> <hr/> <p>King and Lenox [14] review that scholars have critics: “efforts to increase the efficiency of throughputs may lead to a greater production of waste. Reducing inventory, for example, may lead to a greater production of waste. The small batch size production inherent in lean production entails more frequent changeovers, and these changeovers might require cleaning of production equipment and disposal of unused process material”.</p> <p>Cusumano [33] and Rothenburg et al. [34] mention that for the reason of reducing congestion and urban air pollution, plants in Japan has altered their just-in-time delivery system, while Sarkis [13] speculates “JIT usually requires supply materials in smaller lot sizes with more frequent deliveries. This may cause greater transportation and packaging related environmental problems”.</p> <p>In McIntyre [35]: “The cost of holding inventory is very high and consequently just-in-time is used. Reducing inventory in this way has a positive effect on cost, but customers are ever more remote and expect faster and more reliable delivery”. Sharing a similar view, Matthews et al. [36] speculates an expected “effect of JIT is that deliveries may be made via faster freight methods (e.g. truck or air instead of rail or water)”, although it is expected that “reduced inventory levels leads to less pollution”. McIntyre et al. [35], with reference to Cooper et al. [37], review that “JIT raises fuel consumption as smaller lorries consume more fuel per ton of goods moved than larger vehicles. The use of combined transport options, such as containers using road and rail links, is advocated for environmental improvement”.</p> <hr/>
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**Figure 6** The shape of analysis suggested in the case of postponement example

Shifting from Full speculation to Logistics postponement			
	Type of change	Environmental advantages	Environmental disadvantages
Production	–		
Packaging	to: Standardisation	<ul style="list-style-type: none"><li>• Better control of waste at the end of the chain</li></ul>	
Warehousing	to: Centralisation	<ul style="list-style-type: none"><li>• Less material &amp; energy consumption</li><li>• Less land use impact</li></ul>	<ul style="list-style-type: none"><li>• Loss of old infrastructure of warehousing</li></ul>
Transportation	to: Shipping only to order and cross-docking	<ul style="list-style-type: none"><li>• Less waste of unsold items</li><li>• Less extensive transport network</li></ul>	<ul style="list-style-type: none"><li>• Faster mode</li><li>• Lower filling grade</li><li>• Smaller packages (further waste)</li></ul>
Opportunities	- Use of combined transport options such as containers using road and rail links - Future use of friendly truck system		
Obstacles	- Inapplicability of shifting, for some types of merchandise		
Shifting from Full speculation to Manufacturing/packaging postponement			
	Type of change	Environmental advantages	Environmental disadvantages
Production	to: Final differentiating steps in decentralised points	<ul style="list-style-type: none"><li>• Less waste during manufacturing and waste of unsold items</li></ul>	<ul style="list-style-type: none"><li>• Longer set-up times</li><li>• More difficult control of waste at the end of the chain</li></ul>
Packaging	to: Labelling/packing when orders are requested	<ul style="list-style-type: none"><li>• Less waste of unsold items</li></ul>	<ul style="list-style-type: none"><li>• Longer set-up times</li><li>• More difficult control of waste at the end of the chain</li></ul>
Warehousing	–		
Transportation	–		
Opportunities			
Obstacles	- Inapplicability of shifting, for some types of merchandise		
Shifting from Full speculation to Full postponement			
	Type of change	Environmental advantages	Environmental disadvantages
Production	to: Mass customisation	<ul style="list-style-type: none"><li>• Less waste during manufacturing and waste of unsold items</li></ul>	<ul style="list-style-type: none"><li>• Longer set-up times</li><li>• More difficult control of waste at the end of the chain</li></ul>
Packaging	to: Standardisation and labelling/packing when orders are requested	<ul style="list-style-type: none"><li>• Better control of waste at the end of the chain</li><li>• Less waste of unsold items</li></ul>	<ul style="list-style-type: none"><li>• Longer set-up times</li><li>• More difficult control of waste at the end of the chain</li></ul>
Warehousing	to: Centralisation	<ul style="list-style-type: none"><li>• Less material &amp; energy consumption</li><li>• Less land use impact</li></ul>	<ul style="list-style-type: none"><li>• Loss of old infrastructure of warehousing</li></ul>
Transportation	to: Shipping only to order and cross-docking	<ul style="list-style-type: none"><li>• Less waste of unsold items</li><li>• Less extensive transport network</li></ul>	<ul style="list-style-type: none"><li>• Faster mode</li><li>• Lower filling grade</li><li>• Smaller packages (further waste)</li></ul>
Opportunities	- Use of combined transport options such as containers using road and rail links - Future use of friendly truck system		
Obstacles	- Inapplicability of shifting, for some types of merchandise		

# PAPER 3

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# Eco-efficiency in the Era of Electronic Commerce – Is There a Need for Adopting ‘Eco-effectiveness’?

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**Abstract** *In the 1980's, when PCs were first introduced on the market, people aspired to a vision of a “paperless office”; but unfortunately the development at present tends to be quite the opposite. Nowadays, there is too great an optimism regarding Information technology in general, and E-commerce in particular. Will E-commerce turn out to be another utopia or a success story? The current literature gives an incomplete picture of the industrial control tools – environmental efficiency and effectiveness –, would this have any effect on the success of E-commerce advancing towards sustainable development? This paper is based on content analysis and concept development methods. We find that there is a value in and a need for considering the potentials of the ‘eco-effectiveness’ metaphor. However, to have a greater influence, the current form of this terminology should be expanded. It is entirely beyond the scope of this paper to show that eco-effectiveness is better than eco-efficiency.*

**Keywords** *Electronic commerce, Eco-efficiency, Eco-effectiveness, Environmental efficiency, Environmental effectiveness, Dematerialisation, Information technology*

## Introduction

Nowadays, there is too great an optimism that information technology, including electronic commerce (E-commerce), will lead to vast environmental benefits. In the 1980's, when PCs were first introduced on the market, people had aspired to a vision of a “paperless office”; but unfortunately the development at present tends to be quite the opposite<sup>1</sup>. E-commerce is as yet at the beginning of its development and is still growing. Whereas nobody knows where it will end in the years ahead, the expected form and extent of the implications E-commerce may give rise to, cover a wide range of industrial processes and supply chains. The point of risk here, much more than in the case in the eighties, is that this technology can influence the whole system of economy (the sum of all products systems<sup>2</sup>).

A second observation is that ‘environmental effectiveness’ is not a recognised or utilised term, although ‘effectiveness’, in general, plays a complementary role to the term ‘efficiency’ as can be seen in many engineering disciplines. For example, in supply chain management and logistics discipline (where several engineering disciplines are interacting and where life cycle thinking and systems analysis are the bases), “efficiency is related to the internal activities of a company or a supply chain, while effectiveness is externally related.” “Efficiency should (...) be measured internally, while effectiveness is best measured at the interface with end-customers” <sup>3</sup> (Figure 1). Efficiency and effectiveness are considered two critical dimensions of customer value <sup>4</sup>. They are in fact a way for companies to differentiate themselves, either by satisfying an optimum cost and quality (efficiency), or by fulfilling the needs of the customers by focusing on quality and convenience (effectiveness) <sup>5</sup>. Also, one can find a broad definition as the following <sup>3</sup>:

- Efficiency: *Doing things in the right way* (comparing output to input).
- Effectiveness: *Doing the right things* (comparing an accomplished work to a planned target)

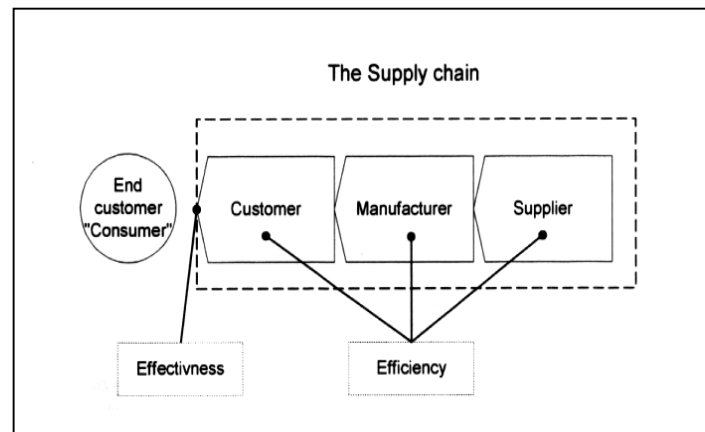


Figure 1. Measuring efficiency and effectiveness in supply chains  
(After Holmberg, 2000) <sup>6</sup>

To emphasise further the importance of these terms, ‘efficiency’ and ‘effectiveness’ represent the tools for industrial control. Accordingly, from an environmental perspective, they are supposed to constitute the way society is dealing with environmental problems, or in fact the “mentality” in response to them.

Would the above observations impart any indications of a “loose environmental control”, in particular over the issue of E-commerce? Is society ready to deal with the phenomenon of E-commerce in such a way that it does not become another utopia? What suggestions can be provided in this respect? The purpose of this paper is to shed light on these observations and questions, and illuminate the environmental terminology of efficiency and effectiveness in the perspective of E-commerce.



## Methodology

This paper is based on the content analysis method on the environmental terminology of efficiency and effectiveness, combined with the concept development method in order to reflect demands of E-commerce on the potentials of the available terminology. The content analysis was conducted through triangulation among sources. The sources surveyed were:

1. Technical dictionaries,
2. Main references in the subjects of Industrial Ecology, Design for Environment, and ISO14000,
3. Expert opinions, and
4. Electronic databases: Ingenta, ABI/Inform, IEEE Xplore, Ebsco, in addition to the world-wide-web.

## An Overview

One definition of E-commerce (among many available) is: “any form of business transaction in which the parties interact electronically rather than by physical exchanges or direct physical contact” <sup>7</sup>. E-commerce is known to public simply as: shopping through the Internet. This commerce transaction may be between the customer and the business sector, or from business to business. The book and CDs/soft-ware trade, among a few, is one example of successful trade in using E-commerce. Yet, this technology is also developing for some other types of merchandise <sup>8, 9, 10</sup>.

There is an anticipation that E-commerce will render great environmental benefits. The proponents of this technology believe that a good deal of personal transport (private cars) will be reduced, mass production will shift into mass customisation, thus saving resources by lower inventory levels and less waste generation throughout the life cycle, paper consumption will truly come down, and more <sup>11, 12</sup>. E-commerce is expected to contribute to a dramatic reshaping of future cities <sup>13</sup>. Nevertheless, what is available currently is rather based on anecdotal evidence or only speculations to support these claims <sup>11, 12, 13, 14</sup>. On the other hand, there are opponents who are not optimistic about this issue, but also their arguments lack sufficient evidence.

### *E-commerce & Dematerialisation*

In the first place, it is necessary to be aware of the fact that Information technology (IT), Internet and E-commerce are not synonym. E-commerce is only one of several activities served by the Internet, which is only one form of IT. Electronic Data Interchange (EDI), another IT form, also offers E-commerce transactions. Therefore, IT, Internet and E-commerce, each provides different examples of dematerialisation potentials.

Dematerialisation has been for a long time associated with our endeavours to achieve a successful sustainable development. Dematerialisation “is often used in a broad sense to identify

a process in which the total weight of materials used in industrial products has declined over time”<sup>1</sup>. In some instances, another term, “E-materialisation” is used where the products (or services) are transformed into electronic form via the Internet such as films, CDs, books, journals, soft-ware, etc.

In general, “dematerialisation can be realised by several means such as process improvement, product improvement, product to service conversion, and structural change. Different applications of IT can play a role in the realisation of some dematerialisation through all these means”. Some examples are<sup>1</sup>:

- Process improvement (ex: digitalisation of printing processes, telecom switchboards)
- Product improvement (ex: miniaturisation of computers, mobile phones, telephone catalogues, etc.)
- Product-to-service conversion (ex: airmail becomes email, newspapers become online news, journals become online electronic databases, etc.)
- Structural change (ex: tele-working, related to a reduction in office space and transportation needs, another example is using EDI, related to reduction in administrative documents, etc.)

“In addition, selling a function instead of a product can be seen as yet another step toward dematerialisation”<sup>1</sup>.

For E-commerce, the potentials of dematerialisation are classified in terms of product type or phase type. For the first, there is product-based E-commerce (ex: purchasing of CDs) and Information-based E-commerce (ex: online banking and online music downloading)<sup>15</sup>. For the latter, there are three phases between the buyer and the seller: communication, delivery, and payment. Some examples follow: vanishing of stores (the communication stage), reduction of amount of transport (the delivery stage), paying by online forms such as online banking (the payment stage) (Source: Wuppertal Institute, cited by Digital Europe)<sup>15</sup>.

### *Environmental Assessment of E-commerce*

At the gate of environmental assessment, there is little help or indications of the environmental profile of E-commerce. In the current literature on evaluating the environmental implications of E-commerce, there are to date a good deal of pilot studies, interim reports and anecdotal arguments, speculations, and a limited number of LCA assessments of E-commerce. The main observation is that there are difficulties in generalising the results, and sometimes results are conflicting. Some reports are proponents of the positive impacts of E-commerce, and some opponents are not optimistic about the total impacts. Nevertheless, there is a general agreement that it is highly difficult, if not impossible, to state whether the environmental negative effects of E-commerce can outweigh the positive effects<sup>14</sup>. In total, the situation looks markedly vague.

In general, the impact/implications of E-commerce are categorised into three forms:

- The impact of its infrastructure (the installed cables, PCs, hardware, etc.),

- The impact of using E-commerce (in a form of impact on various industrial processes of production, transportation, packaging, warehousing, etc. Several challenging trends can be expected, for example, differentiation (the obverse to standardisation) of products and packages, mass customisation, centralisation of warehousing, etc <sup>8, 9, 10, 16</sup>, and
- The impact of rebound effects, for instance:
  - Substantial change in consumption patterns, which are tricky to predict and forecast.
  - Overwhelming number of returns of unwanted or failing products.
  - Substitution of shopping trips by leisure or other types of trips.

## Results of the Content Analysis

### *Environmental Efficiency & Effectiveness*

Table 1 summarises the definitions found in: English Dictionaries, Engineering Encyclopaedias, and Environmental Dictionaries/Glossaries.

We found a definition for the environmental efficiency in an article <sup>17</sup> as: “the reduction of environmental impact through more efficient use of materials and natural resources in manufacturing, is driven in large part by process and operational decisions that would fall under the category of pollution prevention”. In another reference <sup>18</sup>, we find that the “eco-efficiency portfolio” (where the environmental burden and the total economic costs are plotted on a two-axis graph) is a key to determine the product’s environmental efficiency.

Further, we consulted two scholars in the environmental field:

1. *Udo de Haes, Helias* <sup>19</sup>: through a personal communication (2002) by email, he responded that: “The distinction between efficiency and effectiveness must come from economy. But the terms are not always sharp there. Effectiveness: the degree to which you reach your aim. Efficiency: the same, but then divided by the costs. I cannot directly point to literature here”
2. *Schenck, Rita* <sup>20</sup>: through a personal communication (2002) by email, she responded that: “Environmental efficiency refers to products and processes that provide goods and services with lower environmental impacts. An example is a fluorescent light bulb, which produces the same amount of light while using 1/4 or the electricity used by an incandescent light bulb. Environmental efficiency is also called eco-efficiency. Environmental effectiveness is not a term of practice, so its meaning will depend on its use. Possibly it refers to eco-efficiency. Possibly it refers to environmental engineering or management techniques that support environmental quality”.

Table 1. Summary of the definitions of the terms environmental efficiency and environmental effectiveness

		The Definitions	
Name of Dictionary		Efficiency	Effectiveness
English Dictionaries	Cambridge Dictionaries <sup>21</sup>	<i>"The efficiency of a machine or an engine is the difference between the amount of energy that is put into it in the form of fuel, effort, etc. and the amount that comes out in the form of movement"</i>	<i>"Something can be described as effective if it produces the results that it was intended to"</i>
	Merriam-Webster Dictionary <sup>22</sup>	<i>"Productive without waste"</i>	<i>It is rather an economical term presented as 'Cost-effectiveness' to describe how much a process is "economical in terms of tangible benefits produced by money spent"</i>
Engineering Encyclopaedias	McGraw-Hill	<i>The common meaning is "the ratio, expresses as a percentage, of the output to the input of power (energy or work per unit time)"</i>	<i>Described through a phrase 'effective dose': "to characterize the potency of a drug by the amount required to produce a response in 50% of the subjects to whom the drug is given"</i>
	Encyclopaedia of Science and Technology <sup>23</sup>		
Environmental Dictionaries	Longman Dictionary of Environmental Science <sup>24</sup>	<i>None</i>	<i>None</i>
	Encyclopaedia of Environmental Science and Engineering <sup>25</sup>	<i>None</i>	<i>None</i>
	Encyclopaedia of Energy Technology and Environment <sup>26</sup>	<i>The general common meaning as being the measure of the body's performance – the ratio of output over input</i>	<i>(in the environmental section of the Encyclo.) We find only the term 'cost-effectiveness analysis' **</i>
	US Environmental Protection Agency (a website glossary) <sup>27</sup>	<i>None</i>	<i>None</i>
	The Soil Science Society of America (a website glossary) <sup>28</sup>	<i>None</i>	<i>None</i>
	U.N. Enviro. Prog. (A Projects' Manual on the Net) <sup>29</sup>	<i>"How cost-effectively inputs are converted into outputs and results are achieved"</i>	<i>"A measure of the extent to which a project or programme is successful in achieving its results"</i>
	Environmental Economics Glossary (A consultancy website) <sup>30</sup>	<i>"The allocation of goods to their uses of highest relative value" ***</i>	<i>None</i>

**\*\*** This analysis "involves comparison of the costs of alternative approaches to achieving a specific objective, e.g., a reduction in pollution. Unlike benefit-cost analysis, which requires monetization of both the benefits and costs of the proposed action, cost-effectiveness analysis does not require that benefits be expressed in monetary terms. Instead, benefits are expressed as the reduction in different types of damages or sources of damages, e.g., decreased risk of mortality or decrease in the concentration of the pollutant in a body of water. A cost-effectiveness can be assessed by choosing a target level of effectiveness (or goal) for which the least-cost alternative is identified".

**\*\*\*** "Allocative Efficiency: Obtaining the most consumer satisfaction from available resources" <sup>30</sup>.

### *Eco-Efficiency*

“Promoted heavily by the World Business Council for Sustainable Development, for more than a decade it has been the environmental leadership strategy of choice for most of industry, focusing on efficiency to reduce the environmental damage of traditional industrial processes” <sup>31</sup>. This term is an established one and the most commonly used in the field of environmental management. Similar explanations of this term can be found in several references:

1. One definition is: “the ability of a managed entity to simultaneously meet cost, quality, and performance goals, reduce environmental impacts, and conserve valuable resources”, where the “entity” is a product or a process <sup>32</sup>.
2. “Eco-efficiency, cleaner production and lean production are based on a common philosophy: to reduce “waste” in all steps of a production process. Eliminating waste will lead to improvements in eco-efficiency and thus contributes to: less energy consumption, less waste material, less materials handling, and less intermediate storage” <sup>33</sup>.
3. The “call for a new management philosophy aimed at steering the course of a company in a direction that will reduce the overall input of nature per unit of output” is the aspiration of the term eco-efficiency. This term represents “an overlap between economic efficiency and ecological efficiency” <sup>34</sup>.
4. “It has been developed by business for business. The first word of the concept encompasses both *ecological* and *economic* resources – the second says we have to make optimal use of both. One important aspect of eco-efficiency in practice is resource productivity – doing more with less. Reducing waste and pollution, and using fewer energy and raw material resources, is obviously good for the environment, and making better use of inputs translates into bottom-line benefits. These benefits potentially will increase as governments implement plans to change market frameworks in order to make resources and pollution more expensive. Eco-efficiency focuses as well on creating additional value by better meeting customer’s needs while maintaining or reducing environmental impacts” <sup>35</sup>. As a summary, “eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resources intensity throughout the life cycle, to a level at least in line with the earth’s estimated carrying capacity” <sup>35</sup>.

### *The Eco-Effectiveness Metaphor*

Eco-effectiveness is still a metaphor proposed in recent years and is not yet established or commonly applied or even commonly believed in. It “is used in different ways. It was used by Schaltegger and Sturm (1990, 1992, 1998) <sup>36</sup> in the sense of technical effectiveness, which complements the economic value orientation of eco-efficiency. Braungart and McDonough (Braungart, 1994; Braungart and McDonough, 1998; MBCD, 2001) <sup>31, 37, 38</sup> on the other hand use the term in clear opposition to the eco-efficiency” <sup>39</sup>. “Long-term prosperity depends not on the efficiency of a fundamentally destructive system, but on the effectiveness of the processes

designed to be healthy and renewable in the first place. Eco-effectiveness celebrates the abundance and fecundity of natural systems, and structures itself around goals that target 100 percent sustaining solutions”<sup>31</sup>. The basic idea is that eco-effectiveness “leads to human industry that is regenerative rather than depletive,” and “from an industrial design perspective, it means products work within cradle-to-cradle life cycle rather than cradle-to-grave ones”<sup>38</sup>.

One may argue: what is the point about “cradle-to-cradle”; eco-efficiency also is concerned with recycling? On the other hand, it is true that “eco-efficiency (..) does reduce the resulting waste produced by industry, but it does not go far enough. The resulting waste dumps would contain many valuable and rare materials lost to humanity. Thus this would lead to unsustainability in the long run. Hence we have to introduce complete material recycling into industrial production processes”<sup>40</sup>. “Eco-efficiency optimises efficiency and environmental impact, and thus it only reduces the waste associated with industrial activity but does not eliminate it. Hence, it only delays an eventual ecological decline or even collapse facing humanity”<sup>40</sup>. “Although the debate about eco-efficiency is by far from over,” Dyllick and Hockerts<sup>39</sup> argue in their paper that the “issue of eco-effectiveness deserves equal scholarly attention”<sup>39</sup>.

Another way in which this term is used, lies within the framework of the issue of environmental management systems (EMS). “‘Effectiveness’ here means ‘doing the right things’ in order to reach absolute improvements of environmental performance. This goes beyond the common understanding of eco-efficiency (‘doing the things right’), which generally aims at reducing negative environmental impacts per unit of output”<sup>41</sup>.

### *In Summary*

One can conclude that:

1. Eco-efficiency is the most commonly used, established term, and represents our current “mentality” to environmental control.
2. Environmental effectiveness is of no practical use, while eco-effectiveness is an emerging metaphor more likely as a competitor to eco-efficiency.

If one parallelises these terms with the definitions of “efficiency” and “effectiveness” in the field of logistics/supply chain management, a framework can be organised as shown in Table 2. Eco-efficiency in fact looks like a combination of three “entities” namely, SCM efficiency, SCM effectiveness, and Environmental efficiency (meeting costs, quality and reducing environmental impacts).

Table 2. Organising the definitions in the literature in a comparative framework

	Where	Evaluating	What	Focus
SCM Efficiency _____ <i>Environmental efficiency</i>	Inside an organisation/supply chain	Each process	What are the losses? <i>How to reduce waste?</i>	Operations
SCM Effectiveness _____ <i>Environmental effectiveness</i>	Looking at the end	The whole	Have the goals been achieved? <i>Reaching an “absolute environmental performance”?</i>	Serving the market <i>The environment</i>

## Discussion

### *A Need for Eco-Effectiveness*

Rebound effects constitute one of the main drawbacks associated with E-commerce<sup>9, 11, 16, 42</sup>. In the meantime, one can find some power in eco-effectiveness (vis-à-vis eco-efficiency) regarding rebound effects. It has been found that “human beings often use improved efficiency of technology to increase comfort and improve quality of life”. For instance, “in Norway, specific energy consumption per household has increased and not decreased when options for energy conservation have been introduced in private houses<sup>43</sup>”<sup>44</sup>. For instance, “the improvements in fuel efficiency, which have been achieved during the last ten years, have been more than balanced by the increase of use of cars, and the general increase in number of cars in the society”<sup>44</sup>.

In the E-commerce era, it is likely that people will travel for leisure or for other types of trips substituting the decrease in shopping trips (due to home delivery)<sup>42</sup>. It is likely that people will print out the online sales catalogues, and the retailers print out the online orders. It is likely that people will buy and consume more and more<sup>8</sup>. Also, one important trend expected in the next years is increase of mass customisation instead of mass production. Although it looks “good” from an environmental point of view (reducing waste throughout the life cycle); however, there is a hidden negative angle. The effect in this situation is similar to that of, for example, reducing sewage effluent from textile finishing while at the same time increasing the amount of additives used in textiles and therefore still end up with a non-recyclable product (example taken from<sup>45</sup>).

Another point of importance is the reverse logistics facilitating the recycling/recovery of products; E-commerce is hoped to contribute in this regard. “However, it is important to use recovered materials primarily as a substitution for virgin materials in meeting the existing demand in the market, and not provoke new demands to find a use for recovered materials”<sup>44</sup>

(“substitution for virgin materials” indicates eco-effectiveness, and “provoke new demands” indicates eco-efficiency”). With the power of Internet, “better channels for environmental information and feedback loops” <sup>44</sup> would facilitate the cradle-to-cradle thinking of eco-effectiveness further. Therefore, again, eco-effectiveness gains a credit over eco-efficiency in the context of E-commerce. However, eco-effectiveness has to be developed further; the next subsections propose some suggestions in this respect.

### *Extending the Eco-Effectiveness Model*

Despite its relative success to stand against the rebound effects, eco-effectiveness still lacks the human side as a direct influence. This is because with eco-effectiveness the consumption behaviour issue is not solved yet; it is only the technical side of materials, by a “complete recycling system” (cradle-to-cradle), that gets solved. Buying and consuming can still increase, which means there will still be increase in consumption of natural resources (particularly the non-renewables) especially in processes that handle material recovery/recycling and perform transportation from “grave” back to “cradle”. Some scholars stated that our focus might shift from the efficiency of fossil fuel to the effectiveness of solar cells <sup>39</sup>. However, the abundance of energy that solar cells will produce might in itself create a considerable increase of electricity consumption in utilising the infrastructure, in addition to producing the solar cells themselves in large volumes, although one may argue that if the solar energy system is standardised and has a “complete” recyclability (according to eco-effectiveness), then the production impact might be negligible.

Another consideration along the same line is that one of the main advantages of E-commerce transactions (from an SCM/business point of view) is to respond to the demands of customers effectively. This is likely will lead to higher level of differentiation of products and packages <sup>46</sup>. This might encounter more complication and be demanding on the recycling goals of eco-effectiveness. Therefore, we present the following suggestion that, eco-effectiveness should attempt to potentially reengineer the culture and sociology of consumers to pay and maintain more attention to obtaining needed functionality of products or services than just possession of products <sup>47</sup>. So the idea in this connection is to sell the slogan “functionality and not possession” <sup>47</sup>. This can happen if a device that produces the service is shared instead of every individual buying one, or even just all buying the service from the owner of the device. One example, which is growing in some Western countries, is car pools, which is car sharing among people – a group of people subscribes to one or two cars to serve them at any time they need at a small monthly or annual fee for reservation.

Although changing people’s attitudes is not an easy task, the interest and aim should be on making “functionality” more attractive, challenging the wish for “more products”. In one interesting piece of research, Ropke <sup>48</sup> in her review states that “some people hope that the consumption patterns will change, almost by themselves, in a more sustainable direction, because consumers come to a certain degree of satiation with material goods and therefore demand non-



material services". But Ropke <sup>48</sup> questions this and points out that "the contribution from private services has been limited", and that "future possibilities of increasing environmentally benign services meet serious limitations, so active policies are needed to overcome these".

Still, the above thinking ("functionality and not possession") should be complemented with the idea of extending the lifetime of those products by different means of reusing, repairing, remanufacturing, etc <sup>49</sup>. This is because if the product is consumed in a relatively short time, then its value will finally be lost. Yet, it has to be mentioned that in some situations, dumping is more efficient and more cost-effective. Returnable packages, for instance, have not yet been proved to be an environmental choice vis-à-vis one-way packages <sup>50</sup>. For mass-produced items such as complex appliances or some vehicle parts, repair is not cost-effective in comparison to dumping, although there is still a good potential for repair/renovation if manufacturers are given some incentives <sup>49</sup>. This discussion is of importance because E-commerce is expected to push towards a further increase of third party and outsourcing phenomena (terminology of the SCM field) <sup>51</sup>, which are just synonyms to the functionality/leasing idea.

One may argue that there is already a promotion by the term "sufficiency" in response to the consumption topic <sup>34</sup> (Figure 2). However, this is in fact "an issue of individual choice rather than a single firm's responsibility" as most advocates see sufficiency <sup>39</sup>. Although it has a value in influencing the consumer's attitude, it is not a part of eco-effectiveness.

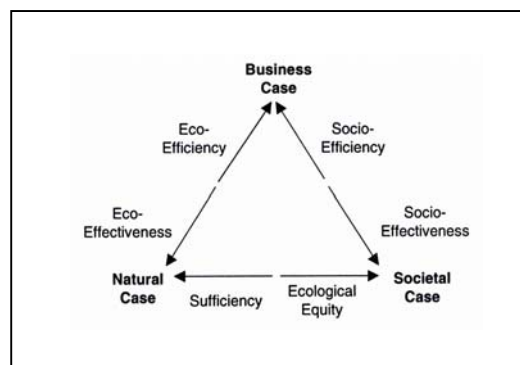


Figure 2. Overview of the six criteria of corporate sustainability  
(After Dyllick and Hockerts, 2002) <sup>39</sup>

### *Further Extending Eco-effectiveness*

In Industrial Ecology, three ecosystem types are defined <sup>52</sup>. "A traditional Type I system is one in which the input of natural resources and output of wastes are not, fundamentally, considered except in an economic fashion, and where there is flow of materials from one lifecycle production process to the other. This is essentially an inactive approach to sustainability although it can

become reactive through imposition of command and control such as pollution constraints”<sup>47</sup>. “A Type II industrial ecological system is one in which there is recycling of wastes and reuse of by-products of one process, either in the same process, or in another one, in order to reduce the resource input requirements and the output waste by-products of the several processes”. “Process redesign and reengineering can potentially enable the Type II system to become a Type III system in which the overall industrial ecological system is closed and there are no (un-renewable) resource requirements and no waste products. This is a proactive approach to industrial ecology and one that ultimately leads to simultaneous human socio-economic development and sustainability”<sup>47</sup>.

We see that in fact eco-efficiency attempts to promote Type II for our industrial systems, while eco-effectiveness attempts to promote Type III. To our knowledge, no scholar has pointed out this connection. We thought this would be another small endorsement of the language and understanding of the eco-effectiveness metaphor vis-à-vis eco-efficiency.

Both terms, in one way or another, advocate four potential “Rs” of environmental design and dematerialisation (“the 4R Strategy”: reusing, repairing/renovating, remanufacturing, and recycling) regardless of the core difference in meanings and forms (eco-effectiveness does not state this directly, however). Some scholars claim that eco-efficiency did not emphasise the 4Rs well enough; on the other hand the recycling (“Upcycling”<sup>38</sup>) in eco-effectiveness is still not a “perfect” thing. For instance, biopolymers are seen as one example of adopting eco-effectiveness strategy due to their good recyclability, biodegradability, and reliance on renewable material sources<sup>31</sup>; nevertheless, “the production of biopolymers like PLA from corn requires much more energy than the production of many types of plastic from virgin petroleum sources”<sup>31</sup>. “In the end, producing biopolymers still consumes significant amounts of fossil fuels”<sup>31</sup>.

One can note that remanufacturing in particular is a core concept to both terms. Nowadays some obstacles, such as lack of vertical integration in the supply chain, hinder the increase in practicing remanufacturing; vertical integration is believed to facilitate further remanufacturing and recycling<sup>49</sup>. Fortunately, supply chain management (SCM) as a concept is in fact all about encouraging vertical integration<sup>53</sup>. SCM, Just-In-Time, E-commerce, etc. are part of a number of industry-wide initiatives towards more global trade. This is the forecast future. Furthermore, both terms imply, by and large, that “dependence on renewables” and “no use of potentially dangerous chemicals in the first place” are two important strategies for the future.

### *Future Research*

Based on the above discussion, we suggest recommend the expansion of eco-effectiveness model into the framework shown in Figure 3. It will be for the benefit of both E-commerce development and ‘eco-effectiveness’ terminology development, to perform E-commerce case studies in an attempt to validate the ideas in this framework. Little value is gained in trying to favour or give preference to eco-efficiency over eco-effectiveness or visa versa; trading off the

shortcomings of eco-efficiency by eco-effectiveness seems of promising value, particularly in complex situations such as that of E-commerce. Both are valuable and, more importantly, they should complement each other. As E-commerce is still in the initial phases of its growth, it is a good time to gain the opportunity for “designing E-commerce for environment”. While it has been shown that an environmental assessment of E-commerce is not of a great value at this stage, it is a better focus that E-commerce is guided during the design stage and not be allowed to freely satisfy market needs without considering the environment <sup>14</sup>.

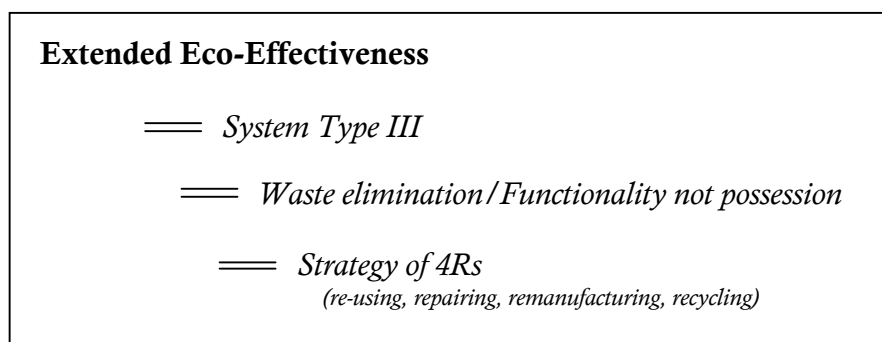


Figure 3. Eco-Effectiveness – extended model

## Concluding Remarks

There is a need for considering the potentials of eco-effectiveness in the era of E-commerce. This does not mean by any means excluding eco-efficiency from our industrial control; this is not our concern. Both are valuable and, more importantly, they should complement each other. Little value is gained in trying to favour or give preference to eco-efficiency over eco-effectiveness or visa versa; trading off the shortcomings of eco-efficiency by eco-effectiveness seems of promising value, particularly in complex situations such as that of E-commerce. There is a need for benefiting from the ideas in eco-effectiveness, specifically in treating the rebound effects, linked to the indirect consequences of efficiency increases. This is a critical point for E-commerce, and thus a more reliable way of control is necessary. Reversing products in supply chains also justifies the need for eco-effectiveness, which is defending a “cradle-to-cradle” metaphor.

Yet, to achieve a greater influence, the eco-effectiveness model has to be expanded beyond its current form in order to consider the “human” dimension. This dimension is related to the still-existing problem of consumption by, for instance, promoting the slogan “functionality, not possession of products”. Furthermore, we suggest that this dimension has to be complemented by motivating “the 4R strategies”: reusing, repairing/renovating, remanufacturing, and recycling; a special concern though is given to remanufacturing. Eco-effectiveness, as we see it, carries ambitions towards System Type III (recall Industrial ecology principles). At this stage of early implementation of E-commerce, the chance to intervene in the design of E-commerce processes should be won; little can be gained by performing environmental assessment works for the time being.

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# PAPER 4

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# Logistics and the Environment: Is it an established subject?

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**Abstract** *The issue of environmental implications of logistics systems is one of the future challenges to logisticians. The purpose of this paper is to explore the logistics and supply chain management discipline to see how the scientific community handles this challenge. Observations in the primary literature revealed that there are weak ties between the logistics/SCM discipline and the environmental discipline. Our analysis indicated that the literature seems to be unbalanced: knowledge about assessing ‘impact of logistics on environment’ is missing, and most emphasis is on ‘impact of environment on logistics.’ Knowledge about implementation comes mainly within reverse logistics literature, which has been described by scholars as exploratory and anecdotal. When comparing the subject ‘log/SC & environ’ with other subjects in the logistics literature, less attention has been paid to ‘log/SC & environ’. Moreover, almost half the articles on ‘log/SC & environ’ are published outside the primary logistics-related journals.*

**Keywords** *Environmental assessment, Reverse logistics, Greening supply chains, Environmentally responsible logistics, Life Cycle Assessment (LCA), Supply chain management*

## Introduction

The environmental implications of logistics systems are increasingly challenging logisticians in terms of requirements towards more conservation of natural resources, reduction of emissions, recycling/reusing materials through reverse logistics means. Are logisticians ready for the future requirements and challenges from the different parties; consumers, governmental organisations, NGOs, etc.? To ascertain the current situation of the environmental subject in the logistics discipline, we have initiated this paper.

Regarding a subject like: logistics and the environment, there is generally a need for two types of discussion: assessment/evaluation discussions, and implementation of measures/solutions discussions. The assessment discussion type entails two ways of presentation: the ‘*impact of logistics on environment*’ and the ‘*impact of environment on logistics*’. By the word ‘environment’ here, we refer to the knowledge in the environmental science/management field, where a main concern in this arena

is studying the interaction of human beings with the balanced nature of its all living and non-living resources. The recent definition of the term 'logistics' by the Council of Logistics Management (CLM, 2002) is: "Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements." A logistical system, therefore, includes four main processes: transportation, warehousing, inventory management, and order processing (Pfohl, 1990; and Lambert, 1998).

Henceforth, the topic: '*the impact of logistics on environment*' is concerned with assessing the impact and influence, either positively or negatively, of a logistical system with its four main processes (including all sub-processes and tasks according to the CLM definition) on the balance of nature with its all living and non-living resources. The obverse is true for the phrase '*impact of environment on logistics*'. It would be more representative, though, that both logistics and supply chain management are mentioned (logistics/SCM), and so instead of the name 'logistics and environment' we use the name 'logistics/SCM and environment' to denote the assessment *and* measure implementation discussions treating the interaction between a logistical system (or a supply chain infrastructure) and the balanced nature of its all living and non-living resources. For convenience in this paper, we use the short name 'log/SC & environ' in place of 'logistics/SCM and environment'.

Generally, research articles on 'log/SC & environ' may have one of three types of focus: a logistics/SCM primary focus, an environmental primary focus, or a shared primary focus. In any case, one expects to find the language of terminology of both logistics discipline and the environmental science discipline in an article on this subject whatever the primary focus may be. Once a considerable number of articles on this subject lack or differently use the language of terminology of one of these two disciplines, this is considered an indication of the need for a bridge to connect these two disciplines. Another interesting indicator for this need can be the non-existence of some types of discussion, either on assessment or on measure implementation.

We have observed that the literature of the logistics discipline through some primary logistics-related journals (as for example: International Journal of Logistics Management, Journal of Business Logistics, International Journal of Physical Distribution and Logistics Management, and some other journals) does not present knowledge about the use of the Life Cycle Assessment (LCA) tool in discussing the impact of logistical systems on the environment. Yet LCA is considered one of the main, most widely used tools in environmental impact assessment (Jönson, 1996). Another observation is that some scholars in the logistics discipline utilize the word 'environment' to denote the outbound forces on the organisations, including the regulations, customers/market, the impact on

natural resources, and some other concerns (examples: see Bowersox and Closs, 1996; and Dewhurst, 2000). A third observation is that we find some scholars who suggest an expansion of the definition of 'reverse logistics' to include not only recycling/reusing but also resource reduction (for example, Carter and Ellram, 1998). But, this suggestion does not coincide with what we find in the environmental field, because resource reduction is considered a proactive approach as one can find in the fundamentals of 'Design for Environment' (DFE) (Fiksel, 1996). Meanwhile, recycling/reusing, which reverse logistics is supporting, is rather a reactive approach as one can find in the fundamentals of 'Industrial Ecology' (IE), (Jelinski et al., 1992).

In total, do these observations above provide any insight into problems in treating the 'log/SC & environ' subject in terms of amount and type of discussions? Our hypothesis was: *The logistics discipline did not give a high priority to 'log/SC & environ' subject as compared to other subjects like business logistics, logistics and management, logistics and information technology, etc.* The purpose of this paper is to show to what extent the primary literature of the logistics discipline treats the 'log/SC & environ' subject in comparison to other subjects like: business logistics, logistics and management, logistics and information technology, and so on. The aim is to highlight the deficiencies in the type of knowledge in the subject of concern.

## Methodology

This paper is based on content analysis work. We surveyed the articles published on the subject 'log/SC & environ' in a list of primary logistics-related journals and primary journals related to other disciplines during the last ten years (i.e. 1992 – 2001). Two lists of journals have been selected, one for logistics-related journals and another for journals related to other disciplines. In the first list, the aim was to ascertain the number of articles published on this subject and on the other subjects in the logistics discipline in order to make a comparison. Meanwhile, in the second list, the aim was to detect only the number of articles published on this subject. To hunt for the articles, we chose to look into each issue/volume of the selected journals instead of using keywords in the search engines of electronic databases.

We selected a list of primary logistics-related journals on the following basis:

- Four refereed logistics-related journals identified previously as the most significant in the field (Emmelhainz and Stock, 1989; Fawcett, Vellanga and Truitt, 1995; and Stock, 1997) are:
  1. *International Journal of Physical Distribution and Logistics Management (IJPDL)*
  2. *Journal of Business Logistics (JBL)*
  3. *The International Journal of Logistics Management (IJLM)*
  4. *Transportation Journal (TJ)*

- Four other refereed primary journals (rather young and hence not included in the evaluation of Emmelhainz and Stock, 1989; Fawcett, Vellanga and Truitt, 1995; and Stock, 1997) handling a wide range of themes in logistics are:
  5. *European Journal of Purchasing and Supply Management (EJPSM)*
  6. *International Journal of Logistics – Research and Applications (IJL)*
  7. *Supply Chain Management – An International Journal (SCM)*
  8. *The Journal of Supply Chain Management (JSCM) (before 1999 called: International Journal of Purchasing and Materials Management)*

Then we selected a list of primary journals related to other disciplines on the following basis:

- The journals should be related to disciplines that have some bridges to the logistics discipline. Disciplines considered are: the operations management, the manufacturing/production management, the business/marketing field, the management field, as well as the environmental field, which we are concerned with in this article.
- Among the many journals related to these selected fields, we selected journals that:
  - a. Gave space for discussion on the environmental concerns for the corporate. The journals considered therefore are:
    1. *Business Strategy and the Environment*
    2. *Environmental Impact Assessment Review*
    3. *Greener Management International: The Journal of Corporate Environmental Strategy*
    4. *International Journal of Life Cycle Assessment*
    5. *Journal of Cleaner Production*
    6. *Journal of Industrial Ecology*
  - b. Have been cited within logistics-related journals. The journals considered are:
    7. *British Journal of Management*
    8. *California Management Review*
    9. *European Journal of Operational Research*
    10. *Integrated Manufacturing Systems*
    11. *Interfaces*
    12. *International Journal of Environmentally Conscious Design and Manufacturing*
    13. *International Journal of Flexible Manufacturing Systems*
    14. *International Journal of Production and Operations Management*
    15. *International Journal of Production Economics*
    16. *International Journal of Retailing and Distribution Management*
    17. *Journal of Operations Management*
    18. *Production and Operations Management*
    19. *Transportation Research – Part E: Logistics and Transportation Review*
  - c. Have been cited or been published in by logisticians who made a work on the subject of ‘log/SC and environ.’ This added the following journal:

20. *International Journal of Technology Management*,

and confirmed some already selected journals (one example of this, in an article on reverse logistics in *Journal Business Logistics*, 2000, we found a citation to an article on reverse logistics published in *California Management Review*, 1979).

- Searching a central, large database called ‘Ingenta’ added the following journal:

21. *Technological Forecasting and Social Change*.

For the task involving the selected logistics-related journals, in order to specify the subjects to compare with ‘log/SC & environ’ subject, the task was approached in two steps:

*First:* we had to build an index of topics that are most presented in the logistics literature. There were some available indices to learn from, for example the subject index for the volumes of the 1990s of *The International Journal of Logistics Management* (IJLM), and the categories presented in a study on the publication contents of *Journal of Business Logistics* (Miyazaki, Philips and Philips, 1999). Ultimately, we made our own index to build a common ground for the eight logistics-related journals surveyed. Table 1 presents our index, which we used to classify all articles published in the last ten years in these eight journals.

*Second:* we then aggregated this twenty-topic index into six categories (Table 2). The reason for categorising was to compare subjects with each other and not to compare topics. We want to compare the environmental discipline (discussed as a subject within the logistics discipline) with other disciplines such as management science, business administration science, marketing science, IT science and so forth. This is why we did not present much discussion for justifying putting specific topics under specific categories. The reader might suggest a different aggregation, but we thought this one probably disturbs neither the general aim of doing the comparison nor the results. The last category, named ‘General titles,’ includes titles that are either of a mixed nature (such as a paper: “Packaging, marketing, logistics and the environment: Are there trade offs?”) or have a total focus on a different discipline (such as manufacturing for example), or rather general (such as a paper: “Logistics trends in South Africa,” “Research frameworks in logistics: three models, seven dinners and a survey”).

## Limitations

Our search was limited to primary publications only and has excluded the trade journals. Some journals are rather young and appeared later than 1992, for example: *International Journal of Logistics – Research and Applications* (ILJ) launched in 1998, and *Journal of Industrial Ecology* in 1997. On the other hand, we had limited access to some other journals, like: *Transportation Journal*, for example, only for the period: fall 1997 – summer 1999. *International Journal of Environmentally Conscious*

Design and Manufacturing was almost inaccessible except for three issues (volume 9, issue 4, 2000, and issues 1, 2 of volume 10 of 2001). The reason for including this journal in this analysis, however, was that we found a cited paper on the subject of concern published in it (1998). There were a number of missing issues of volumes of some journals, but the number was small and negligible (for example: for IJPDLM journal, there were six issues missing out of 98 issues during the ten years, and this was the highest missing percentage).

Table 1. Index of topics under which we classified the articles

Measurement & benchmarking	Just-In-Time (JIT)	IT, EDI and E-commerce	Artificial intelligence	Distribution channels & transportation
Quick response	Lean logistics, re-engineering, and concurrent engineering	Planning	Complexity	Supply chain relationships, partnering and alliances
Quality and cost	Strategy, business and marketing	Outsourcing, third party & logistics services	Inventory management	Order processing and purchasing
SCM, and integrated supply chain	Reverse logistics	Environmental	Education in logistics discipline	General titles

Table 2. The six categories under which the twenty-topic index was aggregated

Categories	Marketing and business	Management	Education in Logistics	Technology, techniques and concepts	Environmental	General titles
<b>Topics</b> (refer to the index built in Table 1)	<i>Quality and cost</i> <i>Outsourcing, third party &amp; logistics services</i> <i>SC relationships, partnering and alliances</i> <i>Strategy</i> <i>(This category has also included titles on competitive strategy, globalisation and exporting/importing topics)</i>	<i>SCM and integrated supply chains</i> <i>Inventory mgmt</i> <i>Planning</i> <i>Complexity</i> <i>Order processing and purchasing</i> <i>(This category has also included titles on logistics organisation, operations research and warehousing topics)</i>		<i>JIT</i> <i>IT, EDI and E-commerce</i> <i>Artificial intelligence</i> <i>Lean logistics, re-engineering, concurrent engineering</i> <i>Measurement &amp; benchmarking</i> <i>Quick response</i> <i>Distribution channels &amp; transportation</i>	<i>(Reverse logistics topic was included in here)</i>	<i>(this category is explained in the text)</i>

While our survey has excluded sections for editorials, discussions, brief notes and conference papers, we also had to exclude the topics that are very new (appeared by 2000) in order that we make a meaningful comparison. Topics excluded are ‘vulnerability in supply chains’ and the ‘agile supply chains,’ which have appeared as recently as the new millennium.

## Results and Discussion

In this section we present first the results covering the logistics journals, and second those covering the other journals, and finally we present an overall discussion.

### *Analysis covering logistics journals*

Figure 1 shows the results in percentages (approximated, with decimals omitted) for the six categories across seven journals out of eight. Transportation Journal was excluded from the figure due to the limited access. In this journal, we found an article published in 1994 related to the subject ‘log/SC & environ’ cited in another article in another journal. We also excluded period 1992 – 1998 of the Journal of Supply Chain Management from the figure, because this journal had a major focus on purchasing and procurement topics when it was known by the old name: International Journal of Purchasing and Materials Management. Instead, for this period, we hunted for the available articles published on ‘log/SC & environ’ and found three articles.

### *Analysis covering other journals*

The results are shown in Table 3. As can be seen in this table, there has been some limited access to some journals, and we cannot be sure whether the un-surveyed volumes have any articles for our concern. One observation was that some of the articles were published in special issues.

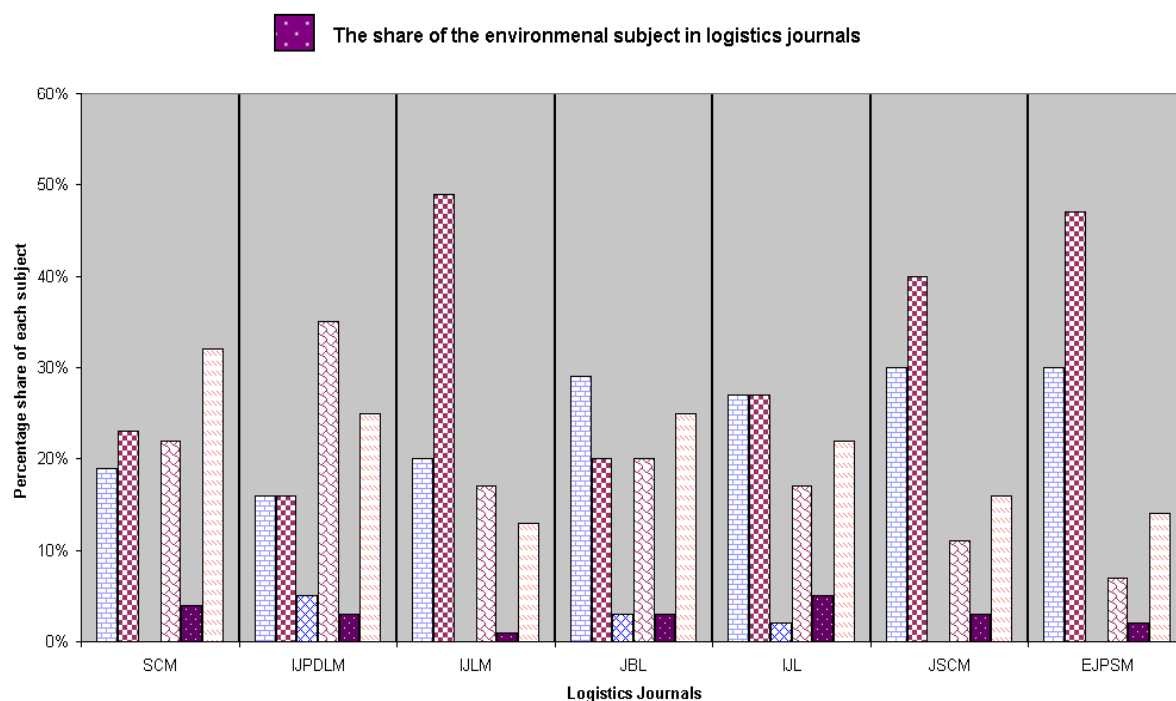


Figure 1. The share of environmental subject in logistics journals

Table 3. Total number of articles published on 'log/SC &amp; environ' in selected journals (1992 – 2002)

Journals, Logistics-related			Journals related to other disciplines		
Name of journal	Number of articles	Period surveyed	Name of journal	Number of articles	Period surveyed
Supply Chain Management	5	1996 – 2001	Journal of Cleaner Production	2	1995 – 2001 (limited access) *
International J. of Physical Distribut and Logistical Management	9	1992 – 2001	Journal of Industr. Ecology	4	1997 – 2001
International J. of Logistics Mgmt	1	1992 – 2001	Envi. Impact Assess. Rev.	–	1995 – 2001 (limited access)
Journal of Business Logistics	7	1992 – 2001	Greener Mgmt Int'l	3	1996 – 2001 (limited access)
International Journal of Logistics	3	1998 – 2002 <small>Vol.5, issue 1</small>	Business Strat & Environ.	2	1996 – 2001 (limited access)
Journal of Supply Chain Management	2 (3)	1999 – 2001 (1992 – 1998)	Int'l J. Life Cycle Assessment	–	1996 – 2001 (limited access)
European Journal of Purchasing and Supply Management	3	1994 – 2001	Int'l J. Consc. Design Manuf	– 1	2000 – 2001 (in 1995)
Transportation Journal	- (1)	1997 – mid 1999 (in 1994)	Int'l J. of Flexible Manufac Sys.	–	1997 – 2002 <small>Vol. 14, issue 3</small> (limited access)
			Integrated Manufac Sys	–	1992 – 2001
			Int'l J. of Prod Economics	1 ( <i>special issue</i> )	1992 – 2002 <small>Vol. 79, issue 1</small>
			Euro. J. OR	–	1992 – 2001
			J. Operations Mgmt	–	1992 – 2002 <small>Vol. 20, issue 4</small>
			Int'l J. of Operations & Prod Mgmt	1	1994 – 2002 <small>Vol. 22, issue 6</small> (limited access)
			Prod Operations Mgmt	4 ( <i>special issue</i> )	1997 – 2001 (limited access)
			Int'l J. Retail Dist Mgmt	1	1992 – 2001
			Interfaces	3	1992 – 2001
			Transportation Research Part E	3	1997 – 2001 (limited access)
			British J. of Mgmt	1 ( <i>special issue</i> )	1992 – 2001
			California Mgmt Review	–	1992 – 2001
			Int'l J. of Tech Mgmt	1 ( <i>special issue</i> )	1996 – 2002 <small>Vol. 24, issue 1</small> (limited access)
			Tech Forecast Social Change	1	1995 – 2002 <small>Vol. 69, issue 7</small> (limited access)
<b>Total Number of Articles</b> (‘log/SC & envi’)	<b>34</b>		<b>Total Number of Articles</b>	<b>28</b>	
			* No access to years outside the indicated range		



### *Overall discussion*

Looking at the total number of articles published in both sides, i.e. the logistics journals and the other journals (Table 3), one may conclude immediately that the number of articles published outside the primary logistics-related journals is considerable, reaching 45% (almost half the total number of articles). However, it seems difficult to make this simple comparison between the totals due to several factors: the number of journals is not equal, the number of issues per year is not equal and the period range surveyed is not the same for all. Yet looking at this matter from another angle disregarding these factors: the interest should be in the total existence of researchers interested in the ‘log/SC & environ’ subject who are expected to produce research articles and submit them to the most appropriate scientific journals where this subject is established. With this understanding, we may then present the conclusion that logisticians have published comparatively little on the ‘log/SC & environ’, and have no clear sense of where to properly publish their findings on such a subject. The assumption then is that the logistics journals are not really yet a favourable place for these kinds of discussions (i.e. ‘log/SC & environ’). Perhaps one supporting indicator for this claim is that some logisticians took the opportunity to submit articles to special issues of journals not related to the logistics discipline (see Table 3).

A different view may question the arrangement of the topics under the six categories mentioned earlier (Table 2), suggesting that more than six categories may be built and the data, therefore, may be cut into smaller amounts of percentages, making the appearance of environmental category not clearly small. But, because the purpose is to compare subjects in a wide context, it would probably be acceptable to arrange the topics in the way we did in Table 2.

The results also show that the Life Cycle Assessment (LCA) tool is rarely presented in the literature as regards ‘log/SC & environ’ except for two articles. One of them (Clift and Wright, 2000) links “the life cycle approach to explore the relationship between environmental impact and added economic value along the supply chain.” The other one (Faruk et al., 2002) presents a new tool as a development and adaptation of LCA to supply chain analysis, in order to ease the process of evaluation and data collection; the new tool is named “Ecological supply chain analysis.” Nevertheless, these two articles are not published in logistics journals (published in *Technological Forecasting and Social Change* journal, and *Journal of Industrial Ecology*). Moreover, LCA is still a tool, focusing on assessment of making a product/service, and this is helpful partially in providing a picture of the whole system performance. There is still a need for another tool to complement and support LCA in a different way (Abukhader and Jönson, 2003).

We found, though, one article that comes close to opening a new door and furnishing a space for a mixed language of logistics discipline and environmental discipline (Sarkis, 1995). However, Sarkis

presents only a general discussion on supply chain management and industrial ecology understanding, with a quick mention of some concepts like Just-In-Time and EDI. We think this is the only article that inaugurates a combined discussion. Notably, this paper is also published outside the logistics journals (in International Journal of Environmentally Conscious Design and Manufacturing).

One may assume that the authors of those three articles selected environmental journals instead of logistics journals because the contents have an environmental primary focus. To recall the journals in which those three articles were published, we find:

- Technological Forecasting and Social Change
- Journal of Industrial Ecology (JIE)
- International Journal of Environmentally Conscious Design and Manufacturing

It is only the second journal (JIE), which belongs to the environmental science discipline. This disproves the assumption about selecting environmental journals instead of logistics journal.

Looking at the type of discussions in all articles treating the environmental subject, we found that the topics, or rather *themes*, can be divided into three groups:

1. 'Reverse logistics': This is rather a logistics discipline topic that involves physical design, and cost and benefits discussions. This topic comes under the 'log/SC & environ' subject because it supports the environmental requirements for recycling/reusing.
2. 'Greening supply chains': This is a discussion on basically the *assessment of the impact of environment on logistics*. It involves discussion of how implementing environmental measures would influence, negatively or positively, the logistics/supply chain infrastructure, and how we can find win-win solutions so that we satisfy the governmental regulations, satisfy the end customers and stay cost effective. Another term used for this theme is: 'environmentally responsible logistics' but the term 'greening supply chains' is more widely employed.
3. 'Emissions assessment': This is the obverse of the second group, i.e. *assessment of logistics impact on environment*. This deals with doing evaluations for the environmental implications of a logistics system/supply chain infrastructure. One tool used is the Life Cycle Assessment (LCA), in addition to a newly proposed tool named "Ecological Supply Chain Analysis (EcoSCAn)."

As can be seen in Table 4, these three themes are not equally addressed and the dominating theme is 'greening supply chains.' For the 'reverse logistics' theme, the number of published articles does not seem to present much progress. Carter and Ellram (1998) argue that "most of the literature dealing with reverse logistics is descriptive and anecdotal." "The majority have appeared in trade publications rather than in academic journals. Most of the research is exploratory, and only very recently have empirical studies been performed." The probable reason for this might be that the "US businesses are

more interested in cost/revenue/service implications of reverse logistics rather than environmental aspects. This would be much different in Europe and elsewhere however” (Stock, 2002). Under the theme ‘emissions assessment’, we find the three previously mentioned articles. It is important, though, to make a clear distinction here: the type of assessment and the language of discussion in those three articles, which have a shared focus on logistics and environment disciplines, differ from the usual LCA assessments articles, which have a primary focus on environmental discipline. The usual LCA assessments are not intended for assessing supply chains but for the full life cycles of products (cradle-to-grave), with virtually little logistics terminology/language in them.

Table 4. Number of articles for the three themes of ‘log/SC & environ’ subject

Theme	‘Emissions assessment’	‘Reverse logistics’	‘Greening supply chains’
In logistics journals	none	13	21
In journals related to other disciplines	3	5	20

## Concluding Remarks

Within the last ten years of publication in eight main logistics-related journals, the ‘logistics/SCM & the environment’ subject has been treated less than the other established subjects in the logistics discipline such as the management science, the business science, the information technology, etc. Almost half the number of the articles published on the ‘logistics/SCM and the environment’ subject are found in journals not related to the logistics discipline; therefore a logistician may not find it easy to access the current literature on ‘logistics/SCM and the environment.’

The contents of all articles found on this subject can be clustered into three themes: ‘greening supply chains,’ ‘reverse logistics,’ and ‘emissions assessment,’ with a large dominance for the first theme. The last theme is almost un-represented in the scientific literature except for three articles. Aside from those three articles, there is no other published work (in primary publications) that discusses the environmental implications of a whole logistics system or a supply chain infrastructure. What is available is the assessment of the environmental decisions impact on logistics & supply chains (the second theme: ‘greening supply chains’). The literature is still discussing the costs and benefits of implementing environmental technologies or strategies for the logistical systems, but not discussing or evaluating the impact of logistical decisions or the performance of a total logistics system on the environment. Even the ‘greening supply chains’ theme mainly derives from another arena known as ‘business and the environment,’ which is established in the business discipline, but presented within the frame of how to be environmentally responsible in logistics, that is how to institute environmental

decisions as part of the value-adding activities of the organisations. The remaining articles are in focus on reverse logistics topic, which is tied to an established concept of the closed loop of life cycles of materials (in the environmental science discipline). Logistics scholars consider this type of research as being rather young and exploratory.

Among the journals surveyed, only three articles tried to demonstrate a connection between the logistics discipline and the environmental discipline, although they are published outside the primary logistics-related journals. Two are works using the LCA method (one of them is a development of a new tool in relation to LCA principles), and the third offers a combination of the language of the logistics discipline and environmental assessment through a general discussion.

## Future Research

As revealed by this study, the research dimension on the impact of logistics on environment is in need for contributions. Necessarily, a good start involves adapting the common, widely used tools in the environmental science discipline (for example LCA) to the logistics/SCM discipline. Part of this, a unique start has appeared in Sarkis, 1995; Clift and Wright, 2000; Faruk, 2002; and Abukhader and Jönson, 2003. The adaptation of environmental knowledge into logistics should include the fundamentals of 'industrial ecology' (IE) and 'design for environment' (DFE), which can rehabilitate the 'log/SC & environ' subject through the dimensions of the assessment discussion or the measures implementation discussion.

Another area of concern for the future is enlarging the effort to disseminate knowledge to other disciplines about what logistics is, being not only "a sort of transportation" as might be understood in some instances. Probably founding a new scientific journal that offers knowledge in logistics (& SCM) and environment would help in this effort, hopefully gathering several disciplines under the environmental umbrella.

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