Integration of Environmental Management and SCM

Jacqueline Bloemhof and Jo van Nunen

ERIM REPORT SERIES *RESEARCH IN MANAGEMENT*	
ERIM Report Series reference number	ERS-2005-030-LIS
Publication	May 2005
Number of pages	18
Persistent paper URL	
Email address corresponding author	jbloemhof@rsm.nl
Address	Erasmus Research Institute of Management (ERIM) RSM Erasmus University / Erasmus School of Economics Erasmus Universiteit Rotterdam P.O.Box 1738 3000 DR Rotterdam, The Netherlands Phone: + 31 10 408 1182 Fax: + 31 10 408 9640 Email: info@erim.eur.nl Internet: www.erim.eur.nl

Bibliographic data and classifications of all the ERIM reports are also available on the ERIM website:
www.erim.eur.nl

ERASMUS **R**ESEARCH **I**NSTITUTE OF **M**ANAGEMENT

REPORT SERIES
RESEARCH IN MANAGEMENT

ABSTRACT AND KEYWORDS	
Abstract	Sustainable supply chain management (SSCM) is a rather new phenomenon in the Operations Management/Operations Research literature. In the design of Sustainable Supply Chains the increase of transparency across the chain is essential and can be obtained through identification and traceability. Sustainable production often means a change in resource-areas and modes of transportation. Investment in sustainability implies innovations in supply chain management with accompanying costs and profits. We present a framework based on product and process innovations that provides insights in the relevant research questions for integrating Environmental Management and SCM. The framework is applied using the literature and practical case studies in this area.
Free Keywords	Supply Chain Management, Closed Loop, Environment, Government Regulations, Sustainability
Availability	The ERIM Report Series is distributed through the following platforms: Academic Repository at Erasmus University (DEAR), DEAR ERIM Series Portal Social Science Research Network (SSRN), SSRN ERIM Series Webpage Research Papers in Economics (REPEC), REPEC ERIM Series Webpage
Classifications	The electronic versions of the papers in the ERIM report Series contain bibliographic metadata by the following classification systems: Library of Congress Classification, (LCC) LCC Webpage Journal of Economic Literature, (JEL), JEL Webpage ACM Computing Classification System CCS Webpage Inspec Classification scheme (ICS), ICS Webpage

Integration of Environmental Management and SCM

Jacqueline Bloemhof[1] and Jo van Nunen

RSM Erasmus University, PO Box 1738, 3000 DR Rotterdam

VERSION MAY 2005

Abstract

Sustainable supply chain management (SSCM) is a rather new phenomenon in the Operations Management/Operations Research literature. In the design of Sustainable Supply Chains the increase of transparency across the chain is essential and can be obtained through identification and traceability. Sustainable production often means a change in resource-areas and modes of transportation. Investment in sustainability implies innovations in supply chain management with accompanying costs and profits. We present a framework based on product and process innovations that provides insights in the relevant research questions for integrating Environmental Management and SCM. The framework is applied using the literature and practical case studies in this area.

Keywords: supply chain management, closed loop, environment, government regulations, sustainability

1. Introduction

A sustainable supply chain meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). Sustainable development is about ensuring a better quality of life for everyone, now and for generations to come.

Sustainable supply chain management refers to all forward processes in the chain, like procurement of materials, production and distribution, as well as the reverse processes to collect and process returned used or unused products and/or parts of products in order to ensure a *socio-economically* and *ecologically* sustainable recovery. The World Business Council for Sustainable Development (2000) states that sustainable business practices are the

[1] Corresponding author, email address: jbloemhof@rsm.nl

key to long-term success of a company. Holliday, chairman and CEO of DuPont in 2001, states that “sustainable growth seeks to make more of the world’s people our customers – and to do so by developing markets that promote and sustain economic prosperity, social equity and environmental integrity (Holliday, 2001).

Sustainable supply chain management was introduced because of consumer awareness and environmental regulation, especially in Europe. The EU Eco-label “Flower”, established some ten years ago, is a certification scheme aimed to help European consumers distinguish more environmentally friendly products and services. At present, the EU flower can be awarded for more than 20 product groups. The ecological criteria are the result of scientific studies, using life cycle analysis (LCA) from cradle to grave, i.e. during manufacturing, use / re-use and final disposal of a product. Important EU regulations regarding sustainability are (i) the General Food Law, Regulation EC/178/2002, (ii) the Waste Electrical and Electronic Equipment (WEEE), Directive 2002/96/EC, and (iii) the directive Emissions Trading Scheme (ETS) based on the world’s first multi-national emissions trading scheme covering greenhouse gases, the so-called Kyoto Protocol.

The General Food Law aims at ensuring a high level of protection of human life, animal health and welfare, plant health and the environment. The food law is based on an integrated ‘farm to fork’ approach, considered as a general principle for EU food policy. One of the main issues in this law is traceability. The traceability of food, feed, food-producing animals and any other substance expected to be incorporated into food or feed shall be established at all stages of production, processing and distribution.

The WEEE Directive is designed to tackle the fast increasing waste stream of electrical and electronic equipments. Increased recycling will limit the total quantity of waste going to disposal. Producers will be responsible for taking back and recovering their equipment. This will provide incentives to design equipment in an environmentally more efficient way, which takes waste management aspects fully into account.

The Emissions Trading Scheme, taking effect in 2005, will cap emissions from 10,000 plants in the oil refining, smelting, steel, cement, glass and paper sectors, and allow trading of their emissions allowances. Companies across 25 countries in the EU must start incorporating climate change into day-to-day commercial decisions, and begin assessing what innovative steps they can take to reduce emissions (Letmathe and Balakrishnan, 2005)

The remainder of this paper is structured as follows. Section 2 introduces the area of Sustainable Supply Chain Management. Section 3 describes a framework for structuring the field of SSCM. Section 4 applies the framework in a review on recent OR contributions to

SSCM. Section 5 illustrates the concepts of the framework with applications of SSCM research in agrilogistics. The results of the survey and the illustrative example are summarized and conclusions are drawn in Section 6.

2. Sustainable supply chain management

Sustainable supply chain management is a rather new phenomenon in the Operations Management / Operations Research literature. Sustainable supply chains can be obtained by optimizing logistic processes using economical, social and environmental objectives.

Traditionally, OR-tools focus on making good trade-offs in supply chain profit optimization. However, the environmental and social impact of a supply chain is becoming increasingly important. OR-tools and methods are potentially useful in making trade-offs in a more sustainable way.

The area of sustainable supply chain management is rather broad. Keywords in this area are reverse logistics, green logistics, industrial ecology, waste recovery management, environmentally conscious manufacturing, product recovery etc. To make the concepts of SSCM more clear, we decided to structure the area in two fields: (i) the Closed-Loop Supply Chain management (CLSC) concept, combining forward and reverse supply chains by closing material flows to limit emissions and residual waste (ii) the Triple Bottom Line concept (3BL), optimizing profit (economy), people (equity) and planet (environment) performance of a traditional forward supply chain. The CLSC concept contains the fields of reverse logistics, waste recovery management and product recovery. The 3BL concept contains the fields of green logistics, environmentally conscious manufacturing, and industrial ecology. Both concepts will be described briefly.

Closed Loop Supply Chain management is an important part of Sustainable Supply Chain Management. In fact, CLSC Management can be seen as the implementation of SSCM at the company level by making sure that society uses and reuses both efficiently and effectively all value that has been put into products. In the long term, reuse of products in whatever way will be beneficial in both environmental and socio-economic respect. Closed-loop supply chain management (Guide and Van Wassenhove, 2003) combines both forward and reverse logistics. Closed-loop supply chains have traditional forward supply chain activities and a set of additional activities required for the reverse supply chain. Recovery practices are framed within the supply chain, and therefore the encircling aspect of the process as a whole is stressed (see Figure 1). CLSC has been stretched out worldwide, involving all the layers of the supply chains in various industry sectors. While some actors in the chain have been forced to take products or packaging back, others have pro-actively done so, attracted by the value in used products. CLSC management emphasizes the importance of coordinating the forward flows with the reverse flows (Dekker et al., 2004). The global nature of closed-loop supply chains requires creative, innovative information technology.

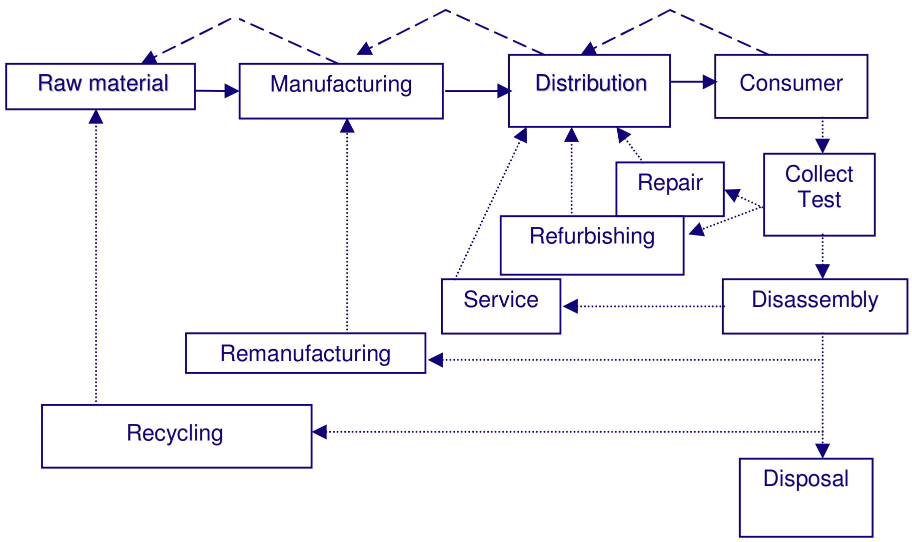

Figure 1: Closed-Loop Supply Chain (CLSC) -concept

The Triple Bottom Line (3BL) Concept, has been focusing specifically on forward logistics, i.e. from producer to consumer (Rodrique et al. 2001). It refers to the dimensions People, Planet and Profit (Triple P), the three dimensions of sustainability. The term Triple Bottom Line is a witticism to the general term bottom line used in Finance. It indicates that Society and Environment are also bottom lines that have to be taken account for. It is a primary organizing principle of 21^{st} century business. ‘Profit’ is a necessary condition for supply chains to guarantee continuity. ‘People’ refers to both the employees in the supply chain as well as the users of products. An important issue here is safety on the work floor and during consumption. ‘Planet’ refers to care for the environment. This means developing products and adapting processes that use less materials and energy as well as limiting direct damage to the environment caused by production and use (such as air emission, soil depletion, etc.). Apart from Triple Bottom Line or Triple P concept, this concept is also known under the name Triple E concept (Economy, Ecology and Equity).

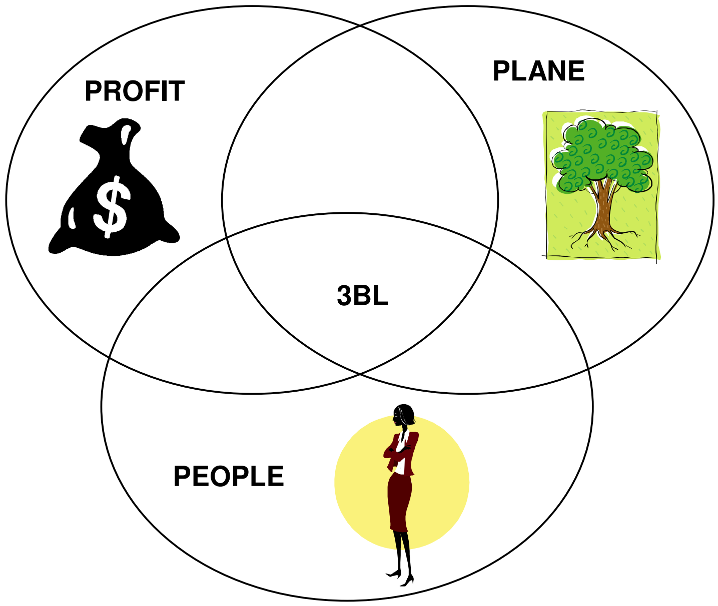

Figure 2: The Triple Bottom Line concept (3BL)

CLSC and 3BL differ fundamentally from traditional forward logistics, because of sustainability requirements (Krikke et al., 2002). Optimizing economic, social and environmental performance requires adaptations in OR modeling. In addition to costs and service, environmental drivers complicate the objective function and the complexity of the system is much higher due to interaction between goods flows. For example, assembly and reassembly of electronic equipment on the same product lines requires adaptations in inventory control and production planning. Warehouses used for the storage of newly produced items as well as recovered items from customers require adaptations in the design of distribution networks. Life cycle driven approaches are essential.

Concepts like Closed Loop Supply Chain Management, Product Life Cycle Approach and eco-eco modeling are still relatively new and unknown in the OR literature. However, the issue of OR and environmental planning has been described for already more than 10 years.

3. Review and Framework

3.1 Review

One of the first examinations of the OR's contribution to environmental decision-making problems is already given by Talcott (1992). In this period, it became obvious that the global nature and the complexity of many environmental problems make it almost impossible to make decisions based on intuition or emotions. The quantitative approach of OR could easily be useful as a rational tool in political debates on environmental issues.

Bloemhof et al. (1995) suggest a framework for the interactions between OR and environmental planning consisting of 2 approaches;
(i) the supply chain approach, research directed towards the source of environmental damage, and (ii) the environmental chain approach, research focusing on the receptors of the undesired effects. Any activity in the supply chain may have an undesired impact on the environmental chain, whereas any disturbance in the ecologic balance may affect product activities in the long run. Daniel et al. (1997) review the literature concerned with the application of OR and environmental issues building on the same framework. Moreover, they classify literature using the stages of problem solving, (i) observation and analysis and (ii) solution identification. Figure 3 illustrates the framework analysis.

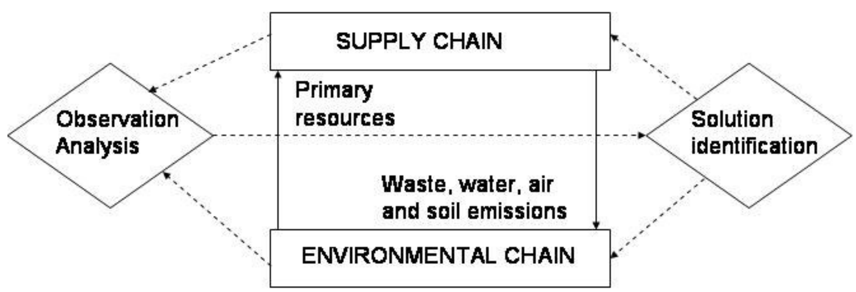

Figure 3: Framework for the interactions between OR and Environmental Management

Recently, a number of reviewing books appeared in the area of closed loop supply chain models. Guide and Van Wassenhove (2003) approach the field of closed-loop supply chain management from a business perspective. They believe that economic incentives (profits) provide the strongest argument in favor of firms developing closed-loop systems. Dekker et al. (2004) address decision making in reverse logistics. The book covers a wide range of aspects, related to distribution, production and inventory management and supply chain management. It explains which quantitative models are available for key managerial issues in real-life examples. Blumberg (2005) gives an introduction to management of reverse logistics and closed-loop supply chain processes including traceability issues like RFID and barcoding. Flapper et al. (2005) give insight in the differences between managing CLSC and supply chains in general. They offer a framework introducing the different aspects related to CLSC as well as cased from successful companies. We refer to the large bibliographies of these books for an overview of papers on Closed Loop Supply Chains. Van Nunen and Zuidwijk (2005) present a framework providing a systematic way of assessing ICT benefits in closed-loop supply chains. The framework is based on a 3x3 matrix combining Management Activities with Perspectives. Closed-loop supply chains can be examined from three perspectives: processes, customers and products. The management activities defined are Control, Monitor and Decide, these activities are necessary to address uncertainty reduction.

3.2 Framework

Based on the framework for E-Enabled Closed-Loop supply chains (Van Nunen and Zuidwijk, 2005) we formulate the following framework for the integration of Environmental Management and SCM.

First, for integrating Environmental Management and SCM it is necessary to determine the most relevant activities. The rows in Table 1 address the underlying management *decision*, a basic question related to *monitoring* the chain and a basic question addressing *control* in the chain. In order to make good decisions, it is essential to obtain information via monitoring and controlling the supply chain.

The approach to define various stages in the process of integrating Environmental Management and SCM is comparable to Daniel et al. (1997). Monitoring and Control are both stages in the process of problem solving that can be described as Observation and Analysis, the first phase in Daniel et al. Research undertaken at this stage usually refers to the pre-intervention phase of projects, where the necessity of undertaking preventive or corrective actions is estimated and appropriate policy directions are examined. Whereas Daniel considers one stage referring to problem identification and analysis, Van Nunen and Zuidwijk split this stage and consider Monitoring (Tracking and Tracing) apart from Control (Sensing and Pacing). The second phase defined by Daniel et al. is Solution Identification, information gathered in the previous stage is used to explicitly or implicitly proceed to a comparative evaluation for selecting the optimal action. This phase coincides with the management decision stage.

Second, we examine SSCM from two perspectives: Products and Processes. The *process perspective* concerns the different processes that occur in SSCM. For example, typical CLSC processes are testing, repair, remanufacturing etc. These processes are difficult to manage due to a number of uncertainties. In the People-Planet-Profit concept, the focus is on the typical

Supply Chain processes like extraction, production, transportation, consumption, pollution. From a *product perspective*, information of the product is captured directly or indirectly from the product itself. Product Life Cycle Management assesses the environmental impact of the product life cycle in order to enable design for environmentally conscious manufacturing. The product perspective and the process perspective are interrelated. If we assess better product information and match those with information of the processes, we can improve the yields of the processes. If we use process information to reduce operation costs or environmental pollution during the processes, we can improve the product value both in economic and environmental sense.

One might say that focussing on the process and product perspectives coincides with the supply chain-environmental chain framework of Bloemhof et al. (1995). The supply chain literature examines modifications in routing and location analysis, production planning and inventory management (process perspective). The environmental chain literature examines the human interference in the ecosystem, measured e.g. by product life cycle management (product perspective). Table 1 can be used to find the relevant questions for each element in the matrix.

Table 1: Framework matrix

		Perspective	
		Process	Product
Activity	Decide	Shift towards production processes with optimal yields both environmentally and economically.	Shift towards large scale central recovery centers.
	Monitor	Can we assess information on the environmental pollution and economic yields of production processes for a given product?	Can we assess information on the state of the product (RFID) to extend the life cycle or identify opportunities for take-back and replacement.
	Control	Can we redesign the production and recovery processes such that environmental and economic performances improve?	Can we design a status log for a product which provides information on usage, failures, etc.

4. SSCM Literature

In the literature we see on the one hand cost (economical) models for supply chain optimization and on the other ecological models aiming at product design improvements. A common framework from which integrated 3P (profit, people, planet) models can be developed is hardly available. Here, we would like to focus on discussing literature in OR journals dealing with the two principles described above:

(i) CLSC: focus on forward, reverse and closed loop supply chains

(ii) TBL: focus on people, planet and profit using multiple objective problem formulations.

Moreover, we show how the framework described above can be applied.

Krikke et al. (2003) deal with optimizing a supply chain design for refrigerators. Designing an optimal supply chain involves a trade-off between supply chain costs and environmental measures like energy use and residual waste. To illustrate the subjective character of an 'optimal' supply chain, the authors use weights assigned to the various objectives. The objective function optimizes deviational variables for each optimization criterion. These non-negative variables express the deficit on an objective function value with respect to a pre-set target value. Target values can be based on legislation (threshold values, emission allowances), expert opinions or business logistics strategy. This method allows comparing the system's performance on different, basically incomparable criteria. They state that many models are built to support product design and logistics separately, i.e. no integration between the process and the product perspective. In this research the authors develop quantitative modeling to support decision making concerning both the design structure of a product and the design structure of the logistic network processes. Therefore, the management decision in this research is taken from a process and a product perspective. Control takes place while comparing the realization values with pre-set target values. These target values (waste, energy, costs) are basically process based. Information on the environmental pollution (monitoring) is assesses for both products and processes.

Nagurney and Toyasaki (2003) develop a framework for the modeling and analysis of supply chain networks with electronic commerce in which the decision makers are faced with multiple criteria, including profit maximization and environmental criteria. Moreover, they allow different decision makers to weigh the criteria in distinct fashion. They establish optimality conditions for manufacturers, retailers, and consumers, and derive equilibrium conditions. The authors consider manufacturers involved in the production of a single product that can be purchased by retailers and/or directly by the consumers. The links in the supply chain include classical physical links as well as virtual links, to allow for electronic commerce. Manufacturers are faced with two criteria: maximizing profit and minimizing total emissions generated in production and transaction. This multi-criteria decision-making problem can be formulated with a value function. Retailers also seek to maximize profit and minimize emissions associated with his transactions with the manufacturers. Consumers take into account the price charged for the product, the transaction costs associated with obtaining the product as well as the emissions generated in their transactions. The behavior of the distinct decision makers forms the base of a super network model. The manufacturers decide with a process perspective (production and transaction), whereas the consumers decide with a product perspective. The focus in this research is more at monitoring than controlling. Monitoring takes place in a process perspective.

D'Agosto and Ribeiro (2004) present a model for road fleet operation, taking into account the traditional approach that strives to minimize fuel consumption as well as wider economic and environmental aspects. "The need to include environmental aspects in energy-efficiency programs is a crucial factor in attaining sustainability". The authors introduce the concept of eco-efficiency. "*Eco-efficiency* considers the skill in measuring the evolution of an economic activity in an environmentally sustainable manner to meet human needs and upgrade the quality of life, steadily reducing environmental impacts and the consumption rates of natural resources, based on the environmental capacities of the planet (World Business Council for Sustainable Development, 2000). The eco-efficiency measures (EM) are performance measures obtained through the ration between product/service value indicators (V) and those for environmental influence caused by generation of use of the product or service (EI):

$$EM = \frac{V}{EI}$$

Product/service indicators are e.g. quantity produced, net sales, and financial costs. Environmental influence indicators are e.g. total energy consumption, greenhouse gas emissions and use of natural resources. The performance measures can be compared with performance targets. The eco-efficiency management program (EEMP) has been evaluated in a case study for the Brazilian's airport authority, on the operation of its road fleet supporting aircraft ground operations. The focus in this research is on deciding, monitoring and controlling from a product perspective.

Oliveira and Antunes (2004) present an economy-energy-environment multiple objective model based on the linear structure of inter-industry production linkages. The aim of the study is to provide decision-makers with a comprehensive model that allows assessing environmental burdens with respect to changes in economic activities consistent with distinct policy measures. The authors use Input-Output matrices adjusted for energy-environment analysis. The focus in this research is on deciding, monitoring and controlling from a process perspective.

Gonzalez-Benito and Gonzalez-Benito (2005) analyze the relationship between environmental proactivity and business performance on a sample of 186 industrial companies. They conclude that there is no one single response for the question of whether environmental proactivity has positive effects on business performance and that this relationship must be disaggregated into more specific and concrete relationships. The environmental management practices are classified in three categories: (i) planning and organizational practices (Environmental Management System), (ii) communicational practices (public image, ISO 14001), and (iii) operational practices. The operational practices are classified in two groups (iiia) the product-related practices (designing ecological products), and (iiib) process-related practices (use of recyclable packaging, cleaner transportation methods, recycling systems, etc). Business performance is measured by financial performance, marketing performance, and operational performance (divided in costs, time, quality and flexibility). Multiple regression analysis is used to test relationships between the classified areas in business performance and environmental management. The authors conclude that operational performance objectives such as quality, reliability and volume flexibility can be improved with more ecological supply chain management and with adequate recycling and reverse logistic systems. This research focuses on both the product and process perspective.

Finally, Letmathe and Blakrishnan (2005) present some mathematical models that can be used by firms to determine their optimal product mix and production quantities in the presence of several different types of environmental constraints, in addition to typical production constraints. Different environmental concerns such as emission thresholds and tradable allowances can be integrated in to production planning methods that currently consider only resource limitations. These models can be used to address environmental concerns and regulations in a proactive manner, rather than in a reactive manner. Decisions are made from both the process and product perspective. Thresholds and allowances (Control) apply to processes.

Based on this literature study, we can conclude that the first steps are taken to somehow simultaneously address multiple issues in production processes and environmental planning, although it remains difficult to obtain a true integration between ecological, equity and economical concerns (Bloemhof et al., 2004a). Table 2 summarizes the contribution of the various authors in the Activity Perspective matrix.

Table 2: Application of the Activity Perspective Matrix

		Perspective	
Activity		Process	Product
	Decide	Krikke et al. (2003) Nagurney and Toyasaki (2003) Oliveira and Antunes (2004) Letmathe, Blakrishnan (2005)	Krikke et al. (2003) Nagurney and Toyasaki (2003) D'Agosto and Ribeiro (2004) Letmathe, Blakrishnan (2005)
	Monitor	Krikke et al. (2003) Nagurney and Toyasaki (2003) Oliveira and Antunes (2004) Gonzalez-Benito (2005)	Krikke et al. (2003) Nagurney and Toyasaki (2003) D'Agosto and Ribeiro (2004) Gonzalez-Benito (2005)
	Control	Krikke et al. (2003) Oliveira and Antunes (2004) Letmathe, Blakrishnan (2005)	D'Agosto and Ribeiro (2004)

5. Sustainable Supply Chain Management in Agro-logistics, an illustration

Sustainable supply chain management can be applied in all sectors of the economy. However, it seems obvious that one of the important sectors will be the agro-logistics sector. For example, the General Food Law focuses on the traceability of food, which will always start in the agricultural part of the chain. Agro-logistics is an important sector. In the Netherlands, more than 20% of good transportation (including import and export) includes agro products. It is not surprising that an international journal for applied agriculture had some special editions reporting on the 'triple bottom line' approach (Mason et al., 2003).

In this section, we apply the framework described in section 3 to define relevant questions in the framework matrix for the agricultural sector and present a preview of forthcoming and ongoing research in the area of sustainable supply chain management in this sector.

5.1 Application of the framework for SSCM in Agro-logistics

The agribusiness has recently dealt with a number of bottlenecks such as animal diseases leading to trade embargos, congestion at the highways, international competition, and stronger legislation regarding food safety and animal well-being. Recently, a number of developments in the society have taken place, influencing the management of agro-logistic flows. These developments are: higher consumer awareness, pull strategy (market) instead of push strategy (producers), fragmentation, scaling-up in retail and agro-distribution, globalisation and liberalisation, sustainable entrepreneurship, sharpened legislation, and more attention for tracing and food safety. The agricultural community has a product-related cluster structure. These clusters are highly independent of each other with very weak ties between each other. They often are called the Pillars of Agriculture. Within these pillars, knowledge is available and people have regular contacts with each other. Between the pillars, the information sharing and communication is quite low. The recent developments and bottlenecks urged the community shift towards a sustainable, innovating and transport-efficient sector (Baalen et al., 2005). Table 3 focuses on the questions related to management decisions that address sustainability improvement strategies by monitoring and controlling of products and processes in the agro-logistics.

Table 3: Questions addressing sustainability improvement strategies in Agro-logistics

	Perspective		
Activity		Process	Product
	Decide	Allocation of production, retail and warehousing processes to locations with optimal yields	To fit with the wishes of consumers, economical and social partners
	Monitor	Can we assess information on the environmental assessment of processes for a given set of products?	Can we assess information on the state of the product in order to identify quality loss or environmental pollution?
	Control	Can we combine production, warehousing and retail processes in such a way that profit and sustainability improve?	Can we design a status log for perishable products which provides information required for safety and sustainability?

In the next section, the questions in Table 3 are answered in order to show how the framework can be applied, based on the results of case studies in the pig husbandry in the Netherlands. The pig husbandry in the Netherlands has changed considerably during recent years. Large scaling up took place leading to the disappearance of small firms and the increase of big firms. Further, the volume of the pig husbandry decreased as a whole with about 20 % in five years time and the image of the sector worsened due to diseases, restricting legislation and fodder scandals.

5.2 Sustainable logistic networks and sustainable products

The cause and effect relationships in Agro-logistics are deeply interrelated. If we improve the sustainability of the processes production, warehousing, distribution, the overall performance indicator of the product life cycle will improve. If we use product information regarding usage, temperature, etc. we can avoid unnecessary transport, improve efficient warehousing etc.

The pig husbandry introduced the Eco-label Pork, which is environmentally and animal friendly produced and of high quality. The Dutch Foundation of Eco-labeling originated in 1992 as a co-production of government, producers, consumers, retail and environmental organizations. It is the Dutch competent body for the European Eco-label. The aim is to stimulate animal and environmentally friendly production using a protected label. The Eco-label can be found on photocopying paper, labels, chairs, shoes, linoleum, writing pads, toilet paper, car polishing products, car-washes, cat litter, organic waste base plates, plants and flowers, bread, apples, pears, onions, barley, wheat, apple juice, potatoes and many other products. In Table 4 we summarize the results of two case studies, one for Eco-label Grain (Bakker, 2003) and one for Eco-label Pigs (Bloemhof et al., 2004b). Eco Label Grain can be defined as grain that fulfills certain criteria on land use, global warming and fossil fuel use. The environmental performance of the grain is calculated by adding up the environmental performance of the grain cultivation in the source-area and the environmental performance of the distribution from source to destination. In Europe, 8 countries are potential suppliers for Eco Label Grain, used for feeding pigs. The choice of a firm to import grain from one of the import countries depends on logistical costs and environmental impacts. Both variables can be combined in a decision support model. In Europe, four different transport modes are available:

- Road (Transportation by truck)
- Inland Sea Shipping (Transportation by inland ship)
- Short Sea Shipping (Transport by sea ship, close to the coast)
- Rail (Transport by train).

Table 4: The Eco-Label Pork case

		Perspective	
Activity		Process	Product
	Decide	Optimize logistic networks for allocating slaughterhouses and wholesalers and optimize trajectory of importing grain to feed the pigs.	Introduction of Eco-Label Pig and Eco-Label Grain
	Monitor	Process traceability to determine what, where and when during the production and handling of products	Product traceability to determine the physical location of items at any stage in the supply chain
	Control	Evaluation model providing environmental performance and economic costs for alternative trajectories.	RFID and DNA data are used for classification of the product (Eco-Label or not)

Monitoring provides the parameters for the costs and environmental performance for each transport mode. Control leads to an evaluation model that compares different origin countries and different transport modes. Monitoring and control support the decision of where and when to buy grain for Eco-label pigs.

Eco-label pigs are pigs that fulfill specific requirements with respect to the feeding, farming and distribution to the abattoir, e.g. a maximum travel time from farmer to slaughter house. This requires traceability from the farm to the abattoir. These data can be used in order to develop an efficient and effective supply chain consisting of farmers, slaughter houses, wholesalers and retailers. An optimization model is built to support decision-making and evaluation of a large number of growth scenarios. Eco-label pigs can be cut into Eco-label pork if again certain requirements during the slaughtering process, the packaging and the distribution to the retailer are fulfilled. Therefore, an integrated traceability from farm to plate might be necessary to optimize the amount of Eco-label pork. Eco-label pork is a high quality product that can be sold at a good price in a high market segment. Investments during the fodder and farming stages in the supply chain are not effective if in the remaining stages of the chain (slaughtering, distribution, retail), conditions are not fulfilled.

6. Conclusions

Operational Research models focus traditionally on cost or profit optimization. Driven by governmental regulations, customer perspectives, and responsible producers, environmental thinking becomes now integrated in the field of Operations Research. The field of Sustainable supply chain management is quite broad:

- Manufacturing and distribution of sustainable –environmentally friendly- products is essential to ensure the use of virgin resources for the future generations. This can be achieved by the TBL concept in the forward supply chain.
- Recovery reverses one-way production and helps to move closer to a sustainable supply chain. This can be obtained by CLSC-models.

We discussed recent literature in OR journals dealing with the two principles described above: (i) CLSC: focus on forward, reverse and closed loop supply chains and (ii) TBL: focus on people, planet and profit using multiple objective problem formulations. We can conclude that these studies support managers in deciding on sustainable products or sustainable processes or both. Before deciding, monitoring and control can be essential in order to make good decisions. Some studies focus on the monitoring and control of processes, some on the monitoring and control of products. In order to obtain a higher level of sustainability, both perspectives of process and product appear to be required.

Moreover, we show how the framework described can be applied for a specific sector, the agrologistics.

References

D'Agosto, M. and Ribeiro, S.K., 2004. "Eco-efficient management program (EEMP)- a model for road fleet operation", Transportation Research Part D, vol. 9, pp. 497-511.

Baalen, P. van, Bloemhof, J.M., and E. Van Heck, 2005. "Knowledge sharing in an emerging network of practice: the role of a knowledge portal", will appear in European Management Journal, June 2005.

Bakker, H.P., 2003. "The way to green grain, Logistical-environmental model for grain import (in Dutch)", Master Thesis, Erasmus University Rotterdam, The Netherlands.

Bloemhof, J.M., Beek, P. van, Hordijk, L., and L.N. Van Wassenhove, 1995. "Interactions between Operational Research and Envrionmental Management ", European Journal of Operational Research 85, pp. 229-243.

Bloemhof, J.M., Krikke, H. and Van Wassenhove, 2004a. "OR Models for Eco-eco Closed-Loop Supply Chain Optimisation", In R. Dekker, M. Fleischmann, K. Inderfurth, and L.N. Van Wassenhove (Eds.), Reverse Logistics, Quantitative Models for Closed-Loop Supply Chains, Springer-Verlag, Berlin Heidelberg, Germany, pp. 357-379.

Bloemhof, J.M., Smeets, C.M., and J.A.E.E. van Nunen, 2004b. "Supply chain optimization in Animal Husbandry", In B. Fleischmann, and A. Klose (Eds.), Distribution Logistics; advanced solutions to practical problems, Lecture Notes 544 in Economics and Mathematical Systems, Springer Verlag, Berlin, pp. 47-64.

Blumberg, D.F., 2005. Reverse Logistics and Closed Loop Supply Chain Processes, CRC Press, USA.

Brundtlandt, G.H., 1987. World Commission on Environment and Development, Our Common Future, Oxford University Press, Oxford-New York.

Dekker, R., Fleischmann, M., Inderfurth, K., and L.N. Van Wassenhove, 2004. Reverse Logistics, Quantitative Models for Closed-Loop Supply Chains, Springer-Verlag, Berlin Heidelberg, Germany.

Daniel, S.E., Diakoulaki, D.C, and C.P. Pappis, 1997. "Operations Research and environmental planning", European Journal of Operational Research, vol. 102, pp. 248-263.

Flapper, S.D.P., Nunen, J.A.E.E. van, L.N. Van Wassenhove eds., 2005. Managing Closed-Loop Supply Chains, Springer-Verlag.

Gonzalez-Benito, J. and O. Gonzalez-Benito, 2005. "Environmental proactivity and business performance: an empirical analysis", Omega 33, pp. 1-15.

Guide, V. D. R. Jr., L.N. Van Wassenhove eds., 2003. Business Aspects of Closed-Loop Supply Chains, Pittsburgh, Pennsylvania, USA.

Gungor, A., and S.M. Gupta, 1999. "Issues in environmentally conscious manufacturing and product recovery: a survey", Computers & Industrial Engineering 36, pp. 811-853.

Holliday, C., 2001. "Sustainable Growth, the DuPont Way", Harvard Business Review 79(8), pp. 129-134.

Krikke, H., C.P. Pappis, G.T. Tsoulfas, and J.M. Bloemhof, 2002. "Extended design principles for closed loop supply chains: optimizing economic, logistic and environmental performance", In Klose, A., Speranza, M.G., and L.N. Van Wassenhove (Eds.), Quantitative approaches to distribution logistics and supply chain management, Lecture Notes 519 in Economics and Mathematical Systems, Springer-Verlag, Berlin, Germany, pp. 61-74.

Krikke, H., Bloemhof, J.M., and L.N. Van Wassenhove, 2003. Concurrent Product and Closed-Loop supply chain design with an application to refrigerators, The International Journal of Production Research 41 (16), pp. 3689-3719.

Letmathe, P. and N. Balakrishnan, 2005. "Environmental considerations on the optimal product mix", European Journal of Operational Research 167, pp. 398-412.

Mason, W.K., K. Lamb and B. Russell, 2003. "The sustainable grazing systems program: new solutions for livestock producers", Australian Journal of Experimental agriculture 43(8), pp. 663-672.

Nagurney, A., and F. Toyasaki, 2003. "Supply chain supernetworks and environmental criteria", Transportation Research Part D 8, pp. 185-213.

Nunen, J.A.E.E. van, R.A. Zuidwijk, 2004. "E-enabled closed-loop supply chains", California Management Review 46(20, pp. 40-54.

Oliveira, C., and C.H. Antunes, 2004. "A multiple objective model to deal with economy-energy-environment interactions", European Journal of Operational Research 153, pp. 370-385.

Rodrique, J.-P., Slack, B., and Comtois, C., 2001. Green Logistics, In Brewer, A.M., Button, K.J., and Henshe, D.A. (Eds.). The Handbook of Logistics and Supply-Chain Management, Handbooks in Transport no. 2, Pergamon/Elsevier, London, UK.

Talcott, F.W., 1992. "Environmental Agenda: the time is ripe for an analytical approach to policy problems", OR/MS Today June 1992, pp. 18-24.

World Business Council for Sustainable Development, 2000. Measuring eco-efficiency, a guide to reporting company performance, World Business Council for Sustainable Development, Geneva.

Publications in the Report Series Research* in Management

ERIM Research Program: "Business Processes, Logistics and Information Systems"

2005

On The Design Of Artificial Stock Markets
Katalin Boer, Arie De Bruin And Uzay Kaymak
ERS-2005-001-LIS
http://hdl.handle.net/1765/1882

Knowledge sharing in an Emerging Network of Practice: The Role of a Knowledge Portal
Peter van Baalen, Jacqueline Bloemhof-Ruwaard, Eric van Heck
ERS-2005-003-LIS
http://hdl.handle.net/1765/1906

A note on the paper Fractional Programming with convex quadratic forms and functions by H.P.Benson
J.B.G.Frenk
ERS-2005-004-LIS
http://hdl.handle.net/1765/1928

A note on the dual of an unconstrained (generalized) geometric programming problem
J.B.G.Frenk and G.J.Still
ERS-2005-006-LIS
http://hdl.handle.net/1765/1927

Privacy Metrics And Boundaries
L-F Pau
ERS-2005-013-LIS
http://hdl.handle.net/1765/1935

Privacy Management Contracts And Economics, Using Service Level Agreements (Sla)
L-F Pau
ERS-2005-014-LIS
http://hdl.handle.net/1765/1938

A Modular Agent-Based Environment for Studying Stock Markets
Katalin Boer, Uzay Kaymak and Arie de Bruin
ERS-2005-017-LIS
http://hdl.handle.net/1765/1929

Keywords Lagrangian duality, cone convexlike functions
J.B.G. Frenk and G. Kassay
ERS-2005-019-LIS
http://hdl.handle.net/1765/1931

Operations Research in Passenger Railway Transportation
Dennis Huisman, Leo G. Kroon, Ramon M. Lentink and Michiel J.C.M. Vromans
ERS-2005-023-LIS
http://hdl.handle.net/1765/2012

Agent Technology Supports Inter-Organizational Planning in the Port
Hans Moonen, Bastiaan van de Rakt, Ian Miller, Jo van Nunen and Jos van Hillegersberg
ERS-2005-027-LIS

Faculty Retention factors at European Business Schools
Lars Moratis, Peter van Baalen, Linda Teunter and Paul Verhaegen
ERS-2005-028-LIS

Determining Number of Zones in a Pick-and-pack Orderpicking System
Tho Le-Duc and Rene de Koster
ERS-2005-029-LIS

Integration of Environmental Management and SCM
Jacqueline Bloemhof and Jo van Nunen
ERS-2005-030-LIS

---

* A complete overview of the ERIM Report Series Research in Management: https://ep.eur.nl/handle/1765/1

ERIM Research Programs:
LIS Business Processes, Logistics and Information Systems
ORG Organizing for Performance
MKT Marketing
F&A Finance and Accounting
STR Strategy and Entrepreneurship