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Managing economical and ecological goal conflicts - demonstrated in the context of Sustainable Supply Chain Networks

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Table of contents

Table of figures

Table of abbreviations

CBA	Cost-Benefit Analysis
CSR	Corporate Social Responsibility
EP	Environmental Purchasing
EPR	Extended Producer Responsibility
ESP	Environmentally Superior Products
GDP	Gross Domestic Product
GSCM	Green Supply Chain Management
ICM	Integrated Chain Management
IE	Industrial Ecology
JIT	Just In Time
LCA	Life Cycle Assessment
LCC	Life Cycle Cost Accounting
NGO	Non-Governmental Organization
OEM	Original Equipment Manufacturer
PPS	Production Planning and Control System
PRPS	Production and Recycling Planning and Control System
QFD	Quality Function Deployment
SCM	Supply Chain Management
SME	Small and Medium sized Enterprises
SPSD	Sustainable Product and Service Development
SSCN	Sustainable Supply Chain Network
TCA	Total Cost Assessment
TCA	Total Cost Analysis
TQM	Total Quality Management

1 Introduction

Sustainable development recently became one of the most and popular expressions of our time in politics, science and business. The development status of sustainability is the result of the activities of three different but closely connected and each other notably influencing main actors. These are: the government, the business sector and the citizens. Although governmental power is the one, which is in the centre of the attention in the media it is not the one which is determinant from the aspect of sustainability. It is rather the business sector.[1] It is the sector which could potentially play the most important role in building a sustainable closed-loop economy.

However, making a move towards sustainability is not possible without integrating ecologic and economic aspects since business organizations are primarily motivated by economic reasons.[2] Integration is not only important from the aspect of the environment and society but also from the perspective of business. Legal regulations and stakeholder pressures demand more environmental responsibility from business and environmental protection can have a positive influence on economic performance.[3] Still, there are possible conflicts between economic and ecologic goals which have to be dissolved to secure that businesses can also stay competitive and sustainable from an economic aspect.[4] It means that solutions which result in better ecologic and economic performance in the same time have to be found.

Managing ecologic and economic sustainability and the dissolution of the conflicts between ecological and economic goals seems to be more effective on a production network level than on a company one.[5] The special literature outlines two basically different network-level concepts. As long as industrial symbioses (also eco-industrial parks and regional recycling networks) have a spatial aspect, green supply chain management (or integrated chain management) has a network one. The supply chain oriented approach is the one which is able to manage the economic and ecological

1 Hutchinson [Environment 1996], pp. 11, van Kleef/Roome [Management 2005], pp. 1.

2 Drechsler [Investment 2005], pp. 5, Fryxell et al. [Reputation 2004], pp. 45, Fryxell/Szeto [Motivators 2002], pp. 223, Kwon et al. [Regulations 2002], pp. 349, Biondi et al. [Systems 2000], pp. 61.

3 Porter/van der Linde [Green 1995], pp. 149, Schaltegger/Synnestvedt [Performance 2002], pp. 339, Hall [Dynamics 2000], pp. 457.

4 Winkler/Kaluza [Networks 2006], pp. 501.

5 Wallner [Industry 1999], pp. 50, Zhu/Cote [Management 2004], 1025, Maxwell/van der Vorst [Products 2003], pp. 890, Gerbens-Leenes et al. [Sustainability 2003], pp. 232.

consequences of a product effectively. The methods of Life Cycle Assessment (LCA), Life Cycle Cost accounting (LCC) and Total Cost Analysis (TCA) can be effectively carried out on a supply chain network level.

In our paper we outline the concept of Sustainable Supply Chain Networks (SSCN) as a tool for integrating ecological and economic goals and dissolving ecologic-economical goal conflicts. We concentrate on management tools contributing to ecologic and economic sustainability in the same time on a supply chain network level. Based on the aforementioned we intend to examine the following topics:

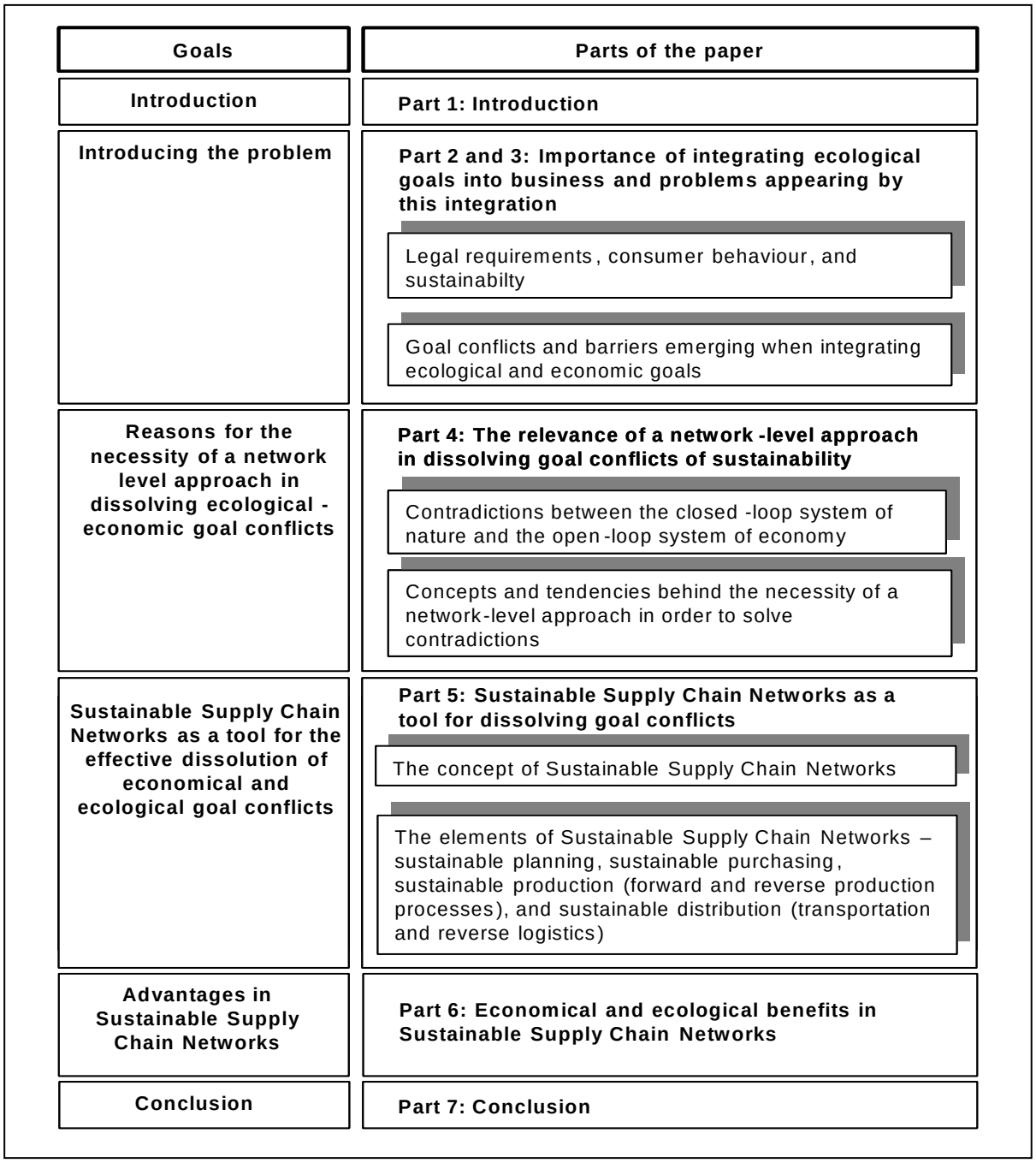

Figure 1: Goals and parts of the paper

2 Importance of integrating economical and ecological goals

Based on the special literature and formal empirical researches we can say that a movement towards sustainability is only possible if we manage to develop concepts integrating both economic and ecological goals.[6] The importance of integrating these goals would not only be important from the aspect of the environment and the society but also from a business perspective since there are more and more outer pressures/drivers which demand business organizations to act at an ecologically responsible way. After analyzing the results of a wide range of empirical researches carried out in connection with corporate motivations regarding environmental investments regulations and consumer pressures found to be the most important drivers regarding environmental investments.[7] Other less important drivers are shareholder pressures, local community, environmental and non-governmental organizations (NGOs), employees and green voters.

2.1 The legal environment as a driver for sustainability

The changing and even stricter environmental legislation and changing business practices, especially outsourcing, emphasize that a network-level thinking of integration of environmental practices is getting more and more important. There is a shift in environmental law towards products (e.g. Integrated Product Policy and Extended Producer Responsibility (EPR) which results in increasing legal, market and financial pressures on manufacturing industries.[8] The essence of EPR is that producers are forced to take back their worn out products but it also prescribes recycling or reusing requirements. EPR requirements found to be gaining importance rapidly in even more countries in a lot of different industries.[9] As it can be seen in figure 2, more than 30 countries apply EPR concerning the different forms of packaging, more than a dozen concerning electronic and electric equipments and batteries and even more countries concerning vehicles and tires. Also, in the EU from

6 Winkler/Kaluza [Networks 2006], pp. 501.

7 Hall [Dynamics 2000], pp. 457.

8 Maxwell/van der Vorst [Products 2003], pp. 883.

9 Renner [Economy 2004], pp. 101.

2006 at least 85% and from 2015 at least 95% of the average weight of an end-of-life vehicle must be recovered whilst the remaining materials may be disposed of.[10]

Production area or Industry	Countries applying Extended Producer Responsibility (EPR)
Packaging	More than 30 countries, e.g. Brazil, China, Czech Republic, Germany, Hungary, Japan, Holland, Peru, Poland, South-Korea, Sweden, Taiwan, Uruguay (only concerning beverage boxes)
Electric and electronic equipments	More than a dozen countries, e.g. Belgium, Brazil, China, Denmark, Germany (only on a volunteer basis), Italy, Japan, Holland, Norway, Portugal, South-Korea, Sweden, Switzerland and Thailand
Vehicles	Brazil, Denmark, France, Germany, Japan, Holland, Switzerland and Taiwan
Vehicle tires	Brazil, Finland, South-Korea Sweden and Taiwan. (Uruguay is planning instructions on a volunteer basis)
Batteries	At least 15 countries, e.g. Austria, Brazil, Germany, Japan, Holland, Norway and Taiwan. (Uruguay is planning instructions on a volunteer basis)
Additionally, there are specific EU regulations concerning EPR. These are mandatory in all 25 EU member countries.	

Source: Renner [Economy 2004], pp. 101.

Figure 2: Some applications of Extended Producer Responsibility

In order to implement sustainable business practices in many sectors, manufacturers need to work very closely together with suppliers since many of them are small and medium-sized enterprises and are not aware of environmental, legislative and eco-design issues. Since many previous manufacturers are now system integrators and outsource design and manufacture of components to companies in the Far East, there is a need to improve cooperation among the different elements of the supply chain if, for example, products are going to be designed for dismantling.[11] The changes in the legal environment highlight the importance of the network-level approach since fulfilling these new and stricter legal requirements does not demand a company level anymore but rather a supply chain and network-level one. There the whole life cycle of a product can be analyzed and managed.[12]

10 Krinke et al. [Life Cycle 2005], pp. 6, Mastny [Purchasing 2004], pp. 169.

11 Lippmann [Management 1999], pp. 179.

12 Kaluza/Blecker [Ensorgungsnetzwerke 1998], pp. 265, Sheu et al. [Logistics 2005], pp. 288.

2.2 The market environment pushes sustainability

Although the relationship between environmental investments and financial performance is quite uncertain among researchers,[13] the opinion that business success can not be separated from sustainability efforts is more than ever common in the international business life. More and more companies integrate environmental aspects into corporate practices and if we take a look at the empirical researches dealing with the motivation of firms by implementing such investments we find that they are indeed motivated by business reasons. Four possible explanations for environmental investments are: stakeholder pressures, competitive positioning, corporate social responsibility (CSR) and financial analysis.[14] Each of these explanations except CSR are business motivated and business motivators appear to a lot stronger extent than the responsibility ones.[15] Similar results appear in the case of supply chain environmental investments. Motives are: market forces, threat of government regulation, maintenance of viability in the chain, improvement of competitive position, power considerations and social forces.[16] These facts show that according to business leaders the role of environmental investments is considered more and more important in influencing business performance.

Since business organizations in the majority of the cases are motivated mainly by economic factors it is important that environmental investments are only going to be introduced when they contribute to corporate success. In this sense the most motivating driver for companies to introduce environmental practices could be “green consumers”. A recent study in Norway found that while until mid 90s it was government regulation which put most external pressure on firms’ environmental performance it is now consumer demand which plays the most important role.[17] Other empirical researches also support the fact that “green consumers” indeed

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13 Vastag/Melnyik [Systems 2002], pp. 4744, Salzmann et al. [Sustainability 2005], pp. 28, Evangelinos/Halkos [Systems 2002], pp. 315.

14 Drechsler [Investment 2005], pp. 5.

15 Fryxell et al. [Reputation 2004], pp. 45, Fryxell/Szeto [Motivators 2002], pp. 223, Granek/Hassanali [Sustainability 2005], pp. 275, Kwon et al. [Regulations 2002], pp. 349, Zhu/Sarkis [Management 2005], pp. 473, Biondi et al. [Systems 2000], pp. 61.

16 de Groene/Hermans [Management 1998], pp. 200.

17 Doonan et al. [Performance 2005], pp. 74.

emerged and green consumerism has become increasingly important.[18] According to approximations the global demand for green products reached an amount of USD 545 billion in 2000. Although this is only one percent of the whole world economy, the tendency is that the market is a rapidly growing one. Green procurement also gains importance in the governmental sector, which's procurement activities reach about 10-25 percent of the gross domestic product (GDP) in the developed world.[19]

Financial and stock exchange comparisons also show that the value and index of shares of firms applying sustainable strategic approaches are render above the average level.[20] Companies' long-term economic success and competitive advantage are dependent on stakeholders like customers, investors, business partners, authorities etc. and their expectations on long term responsibility of the companies. According to the present state of researches, if ecological goals, aspects and activities are properly integrated to business strategy a win-win position is definitely possible.

2.3 Sustainability - the need to integrate environmental goals into business practices

There is currently a strong debate on the concept of sustainable development which does not have a general accepted definition yet. The most known one is the one of the Brundtland committee's, according to which the core of the concept is to satisfy the needs of the present generations in such a way that it does not lower the chance of future generations in satisfying theirs.[21] Accordingly, the present economic activity is likely to narrow the chances of future generations by ruining the global ecosystem on which human society and economy are built on.[22] Based on the Brundtland concept we can formulate the question: To what extent is the use of natural resources and the environment possible, if our economy is to exist on at least on the present level in the very long run? Literature defines three dimensions of

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18 Gerbens-Leenes et al. [Sustainability 2003], pp. 237, Hall [Dynamics 2000], pp. 457, Kumar/Malegeant [Supply Chain 2005], pp. 2.

19 Mastny [Purchasing 2004], pp. 159.

20 For a detailed discussion see Hansmann et al. [Nachhaltigkeitsmanagement 2003], pp.37.

21 WCED [Future 1987], pp. 54.

22 Kaluza/Pasckert [Kreislaufwirtschaftsgesetz 1997], pp. 107.

sustainability: economic, social, and environmental.[23] According to the definition of the International Institute for Sustainable Development and the World Business Council for Sustainable Development, sustainable development means for the business enterprise adopting business strategies and activities which meet the needs of the enterprise and its stakeholders today, while protecting, sustaining and enhancing the human and natural resources that will be needed in the future.[24] A sustainable business has to take into account the interests of future generations, biodiversity, animal protection, human rights, life cycle impacts, and principles like equity, accountability, transparency, openness, education and learning, and local action and scale.[25] These components, just like other ones, emphasize that ecological sustainability means also being responsible for the future generations by sustaining the level of natural resources, which provide essential functions to human society.[26] The role of business in natural resource conservation is extremely important since this is the sector which transforms natural capital into man made one through its production processes.

Empirical evidences suggest that sustainability issues and environmental goals can not be handled separately from economic ones. One proof for that is the so called “green wall” effect. This effect occurs when the overall organization denies moving forward with its strategic environmental management program and the environmental initiative stops as if it had hit a wall. Companies which are trapped within the green wall are caught in the “one step forward one step back phenomenon” in their environmental programs. This means that although individual program activities are moving forward many of them are frozen in status quo.[27] This barrier exists and the reason for it is that environmental experts failed to speak business and could not involve people in important economic positions in corporate environmental protection. These phenomena emerged in the late 80s but the change in business climate has made it even tougher. The reasons are: downsizing became structural and not cyclical by the mid 90s because of the pressure on productivity and also, corporate

23 Wallner [Ökologie 1998], pp. 81.

24 Labuschagne/Brent [Project 2005], pp. 160.

25 van Kleef/Roome [Management 2005], pp. 5.

26 Ekins/Simon [Capital 2003], pp. 257, Ekins [Capital 2003], pp. 278.

27 Nadler [Stairway 1998], pp. 15.

structure is now dynamic and not static.[28] If we want to create tools contributing to sustainability we have to understand that companies are not in business for doing environmental work but for satisfying customers with products or services and stockholders by making money. Therefore any environmental strategy has to be based on understanding how the environmental program fits in with the business.[29]

Since the majority of businesses are not environmentally driven and do not consider environmental issues as business responsibilities, business integration depends on a better understanding between business and environmental objectives.[30] Using arguments of business nature, e.g. cost effectiveness, consumers' concerns and profits, is an effective method when promoting environmental issues[31] since it is unlikely for a company to make a choice that is not primarily economically driven.[32]

3 Economical and ecological goal conflicts in the context of sustainability

Although there are numerous successful examples of integrating ecologic aspects into business, a supply chain network may run into several different barriers when integrating economic and ecological goals.[33] According to one categorization these are *technical* (an exchange is technically unfeasible), e*conomic* (an exchange might be economically unsound or risky from a company perspective), *informational* (the right people do not have the needed information at the right time), o*rganizational* (the intended exchange might not fit in the current corporate organizational structure), and r*egulatory/legal* (caused by the jungle of environmental laws and regulations) barriers.[34] Others create four groups of barriers resulting of goal conflicts by implementing integrated substance chain management.[35] These are: *technological,*

28 Kaluza/Ostendorf [Ökologie 2002], pp. 2, Winkler [Controlling 2005], pp. 1.

29 Nadler [Stairway 1998], pp. 16.

30 Haveman/Dorfman [Green Wall 1999], pp. 6.

31 Doonan et al. [Performance 2005], pp. 74.

32 Byggeth/Hochschorner [Ecodesign 2005], pp. 2.

33 For a detailed discussion concerning the management of goal conflicts see i.a. Fandel [Zielsetzungen 1981], pp. 118, Winkler [Zielplanung 2006], pp. 247, Kaluza [Entscheidungsprozesse 1979], pp. 542, and the quoted literature. For the relationship between ecological and economical goals see i.a. Fritz [Unternehmenserfolg 1995], pp. 347, Meffert/Kirchgeorg [Umweltmanagement 1998], pp. 44. For a critical discussion regarding Fritz see Gemünden/Kaluza [Umweltschutz 1995], pp. 813, and the replica Fritz [Erfolgsursache 1997], pp. 150.

34 Heeres et al. [Eco 2004], pp. 987.

35 de Groene/Hermans [Management 1998], pp. 201.

economic, socio-psychological and organizational/logistics. Although technological barriers do not seem to be real ecologic-economic goal conflicts we still consider them important to examine since they appear because of integrating ecological aspects into business.

Based on these aforementioned categorizations we consider technological, economic, socio-psychological/informational, organizational/logistics and regulatory/ legal conflicts relevant. Since socio-psychological barriers are often the results of informational deficiencies we discuss these two together.

Technological barriers mean that there is no existing technology to reach the desired ecological goals. E.g. products used in the production process are often combined with other materials which can contaminate wastes what makes recycling difficult.[36] It is technically also very difficult to implement a closed-loop supply chain for several categories of products, e.g. perishable products.[37] From an ecologic point of view: the simpler and less robust symbiotic systems are, the more fragile they become since the withdrawal of one organism probably results in the collapse of the whole system unless some redundancy is built in. The larger and more complex the ecosystems are, the less likely is that serious disruptions will occur if one element is suddenly eliminated. Similarly, if one of the key plants in a supply chain network, e.g. the original equipment manufacturer (OEM), closes or purchases its supply elsewhere, it causes serious problems for the system. If one main enterprise looses parts of its market share the whole chain is seriously influenced. It means that on a company level it is financially better to reduce production while on a chain level it worth maintaining the given production level because of other companies being so dependent on the dominant's company co-products, by-products or residual products.[38] Designing a closed-loop supply chain increases this already existing fragility by creating extra uncertainties compared to open-loop ones: e.g. in the timing and the quantity of returns, balancing returns with demand, disassembly, uncertainty

[36] de Groene/Hermans [Management 1998], pp. 209.

[37] Kumar/Malegeant [Supply Chain 2005], pp. 4.

[38] Zhu/Cote [Management 2004], pp. 1031.

in materials recovered, reverse logistics, materials matching requirements, routing uncertainty, and processing time uncertainty.[39]

Economic conflicts mean that there is already a technology present to reach the ecologically desired situation but it can not be used in an economic way. Recycling can be a proper example for that – it is often more expensive than using virgin materials.[40] The reason for that among others is the scarcity of certain materials and the external costs of waste removal are not totally internalized and improved in market prices. Also, switching to a more sustainable production alternative, one with better ecological performance, can prove to be more expensive than the less sustainable one.[41] When processes are changed for ecological reasons and environmentally less harmful materials are used, the quality of the product might also be affected.[42] Another reason for the economic conflict among chain members can be that customers have their environmental expectations towards suppliers but they do not integrate environmental aspects into their purchasing decisions. As a consequence the pricing policy continues to stay the major driver and environmental aspects stay marginal. Environmental investments can also mean significant costs for suppliers at the beginning which can result in conflicts[43] since possible members of the chain, e.g. small and medium sized enterprises (SME), may have limited financial, technical, and human resources which results in a limited capability in environmental performance.[44] Furthermore, maximizing the profits of one chain member in a reverse logistics chain does not necessarily maximize the profit of others which results in conflicts between the members.[45] While information sharing and physical flow coordination can lead to a better supply chain performance up to 35%, benefits are not evenly distributed among channel members.[46] The allocation of the gained positives should lead to a win-win situation but it often causes a high conflict potential because working for the benefits of other organizations can lead to

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39 Kumar/Malegeant [Supply Chain 2005], pp. 4, see also at Chouinard et al. [Reverse Logistics 2005], pp. 106.

40 Sarkis/Rasheed [Manufacturing 1995], pp. 19.

41 de Groene/Hermans [Management 1998], pp. 210.

42 von Ahsen/Funck [Systems 2001], pp. 166.

43 BSR [Supply Chain 2001], pp. 17, Kumar/Malegeant [Supply Chain 2005], pp. 4.

44 Granek/Hassanali [Sustainability 2005], pp. 2.

45 Sheu et al. [Logistics 2005], pp. 288.

46 Sahin/Robinson [Information 2005], pp. 583.

conflicts among chain members.[47] It can also be cheaper for users (both end consumers and industries) to dump waste instead of collecting and returning it to the producer because there are additional transaction costs.[48]

Socio-psychological/informational conflicts emerge from the lack of knowledge and information which can result in the presumptions that the realization of environmental goals is not economic (even if it is in practice) and can cause a decrease in support within the company or among different companies.[49] Human economy evolved for centuries as a linear system building value by moving materials from nature through production and consumption into the environment as waste and pollution. This fact results in a wasting mentality that has been institutionalized in both the business and consumption.[50]

These considerations lead to concrete barriers. These barriers can either be connected to companies or consumers. Regarding companies, workers in different industries may handle waste materials careless which makes separate collection difficult.[51] Empirical studies also suggest that purchasing managers have the perceptions that such programs are not necessarily economic and are expensive to initiate and implement.[52] As a consequence they avoid introducing environmental projects. Furthermore, when e.g. the retailers have the perceptions that consumers will not pay for the necessary recollection tools (e.g. bags or additional transportation systems) and do not understand that recycling could mean extra costs for the OEM it can also result in conflicts among supply chain members because of the missing allocation mechanism of the generated benefits between the supply chain members.[53] Another barrier is the lack of awareness of the closed-loop supply chain, which means that companies tend to focus on their own core business without regarding to the aggregate optimum in ecological issues.[54] In addition a very

47 Kaluza et al. [Supply Chain 2003], pp. 9.

48 de Groene/Hermans [Management 1998], pp. 209.

49 de Groene/Hermans [Management 1998], pp. 201.

50 Lowe [Resource 1998], pp. 45.

51 de Groene/Hermans [Management 1998], pp. 209.

52 Carter et al. [Purchasing 2000], pp. 220.

53 de Groene/Hermans [Management 1998], pp. 209.

54 Kumar/Malegeant [Supply Chain 2005], pp. 5.

important informational barrier is the identification of potential partners,[55] non-cooperative behaviour and lack of willingness to give out information when outbuilding recycling relationships between companies.[56]

An example for consumer behaviour as a real barrier of integrating ecological aspects into business is when consumers are not willing to buy products of better performance and environmental quality because of psychological reasons (e.g. plastic lumber made of recycled plastic is in many ways superior to wood, but wood is still superior for consumers).[57] As a result marketers fear that the use of used products affects their brand image, e.g. as in the case of used tires.[58] Also, the recollection tools do not necessarily seem to be environmentally friendly and users may think that the producer makes money with his return system by making them pay for bags and recycling.[59]

Organizational/logistics conflicts are problems regarding the capacity utilization of the processing installations, or the not fitting of the intended exchange in the current corporate organizational structure[60] and may appear when e.g. a very small amount of often mixed waste is produced. Therefore the building up of reverse logistics can be difficult and expensive.[61] This fact often happens to certain products in the building and construction industry. As a consequence transport systems are also a possible source of barriers because of not reaching the required volume to run an efficient system.[62] Closed-loop supply chains also add complexity to overall supply chain management by influencing issues like product design for recovery, re-engineering, product data management, installed base support, or evaluating (end-of) life scenarios which can be a barrier for the planning and organizational structure.[63]

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55 Schwarz [Verwertungsnetze 1998], pp. 12.

56 Kreikebaum [Ecology 1998], pp. 72.

57 Sarkis/Rasheed [Manufacturing 1995], pp. 20.

58 Kumar/Malegeant [Supply Chain 2005], pp. 4.

59 de Groene/Hermans [Management 1998], pp. 209.

60 Heeres et al. [Eco 2004], pp. 988.

61 de Groene/Hermans [Management 1998], pp. 209.

62 Schwarz [Verwertungsnetze 1998], pp. 13.

63 Kumar/Malegeant [Supply Chain 2005], pp. 4.

The fact that societal and environmental costs of different forms of removal of waste are not necessarily included in market prices can result in *regulatory/legal conflicts*. The goal of environmental legislation should be to internalize such costs instead of keeping them as social ones. It often happens that legislation is not proper from this aspect like in the Netherlands where consumers are paying for placing wastes based on the weight of waste. In case of products of high cubic content and low weight this means that placing it as waste is cheaper than recollection and recycling.[64] The fact that in Austria most residuals are under the restrictive waste law it is often preferable to use virgin input materials for companies than setting up a recycling network and run into the bureaucracy of waste treatment plan approval.[65] Legal requirement can also cause conflicts on a chain level since it is not necessarily clear which actors should wear the burdens of environmental protection, e.g. retailers, producers, suppliers, customers or all of them together, which can cause that any or none of the members is willing to take the responsibility of environmental protection.

Since active participation, investing time, money and other resources into chain development are basic factors of success by eco-industrial networks, dissolving these conflicts is vital for being able to integrate ecological and economic goals into business on both a company and a network level.[66] However, it is more and more accepted in literature that dissolving ecological and economic goal conflicts and in the same time contributing to sustainability by implementing different methods is more effective and also requires – a network-level thinking. In the following we examine the reasons for the necessity of the network-level approach, namely the nature of contradiction between the closed-loop system of nature and the open-loop system of economy, the continuously spreading and developing method of LCA in connection with outsourcing and the requirements of recycling which is a basic enabler of an closed-loop economy and resource conservation. After this discussion we introduce the concept of SSCN as a network-level tool for managing ecological and economic sustainability.

64 de Groene/Hermans [Management 1998], pp. 203.

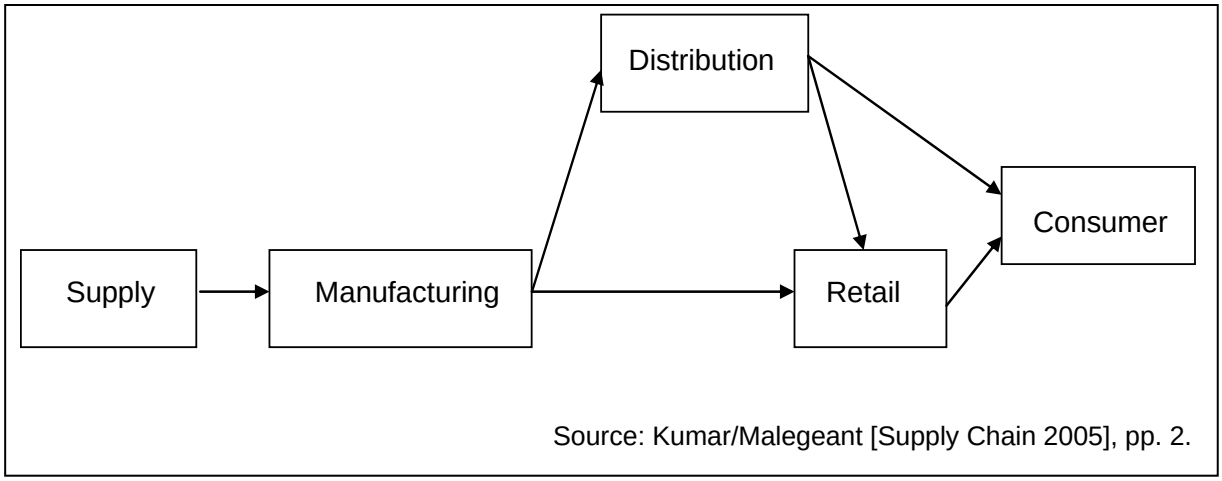
65 Schwarz/Steininger [Network 1997], pp. 55.

66 Heeres et al. [Eco 2004], pp. 987.

4 The relevance of a network-level approach in dissolving economical and ecological goal conflicts

4.1 Contradictions between the closed-loop system of nature and the open-loop system of economy

If we compare industrial systems to natural ones we can reveal several differences among them. In ecosystems all of the emerging “waste” is raw material for other processes. It means that the rate of composition and decomposition is equal, what is essential from the aspect of sustainability because of the constant supply of atoms.[67] Based on such principles an ecosystem is a perfect example of a closed-loop system and has demonstrated its capability for sustainability.[68] In comparison with the traditional way of the supply chain, which is demonstrated in figure 3, it is totally different for at least two aspects. First, manufacturing systems produced an enormous number of new, hardly or not at all decomposable substances (waste) in the past decades, which are possibly able to destroy complex life systems as additional inputs by creating an imbalance in a particular cycle.[69] Second, taking away inputs from nature and not returning them or returning them in a not decomposable form will also ruin natural resources because the constant supply of atoms is interfered.



Source: Kumar/Malegeant [Supply Chain 2005], pp. 2.

Figure 3: Traditional supply chain (forward flow)

In order to create a closed loop economy instead of an open one it is important to re-design the traditional supply chain towards a closed-loop one. A traditional industrial

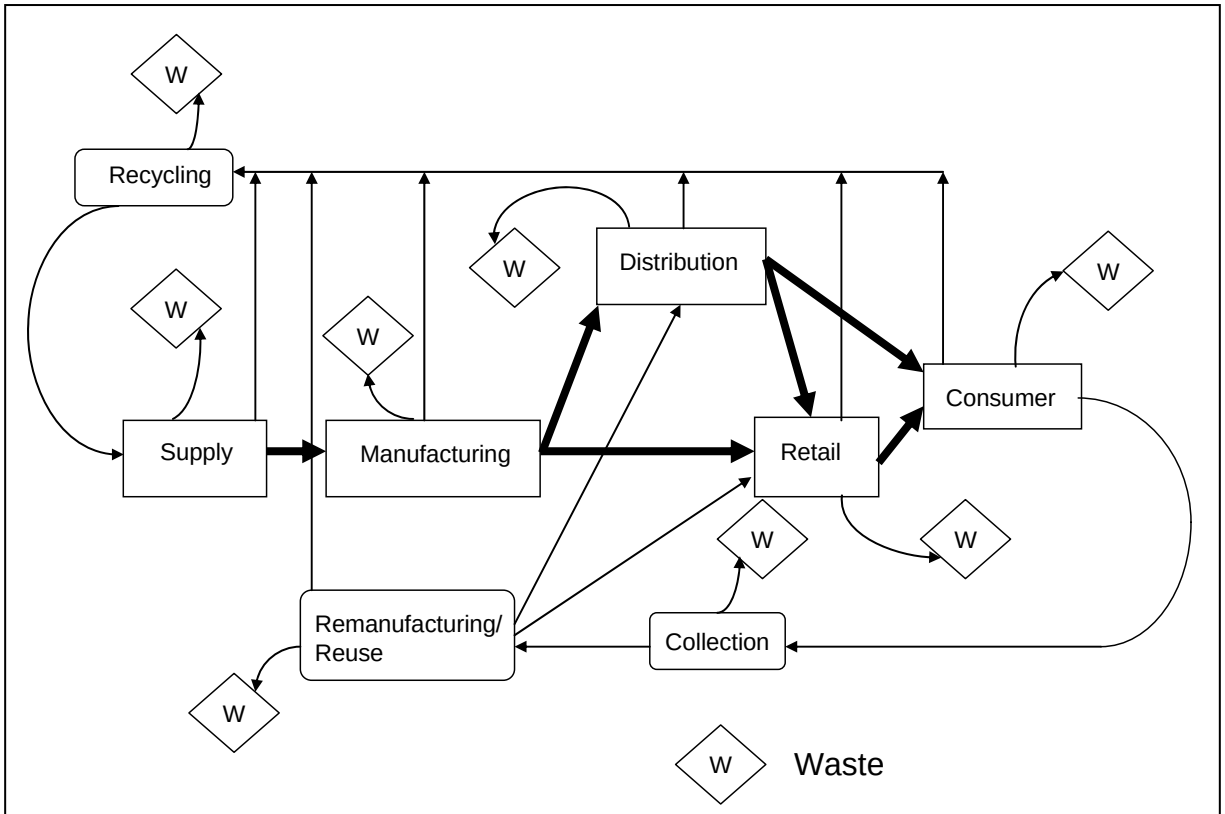
67 Schwarz/Steininger [Network 1997], pp. 48, see the nature of contradiction also at Strebel [Verwertungsnetze 1998], pp. 2.

68 Korhonen [Ecosystem 2001] pp. 254.

69 Schwarz/Steininger [Network 1997], pp. 48.

network or supply chain is build up of different companies which have different functions in creating value for the consumer. A network contains manufacturers of different vertical levels, transportation companies, the OEM and retailers. The resource flow in such a traditional network is one-way (forward).

In contradiction to that, a closed-loop network contains the primary supply chain and one or several supply loops, which collect end-of-life products, waste or production scrap and reprocess them into secondary resources, which replace primary resources in the forward supply chain.[70] It is also clear that the consumers are also to be held as a part of the supply chain in order to make collection and reprocessing more effective. Figure 4 shows the material flows in a closed-loop-network.



Source: Kumar/Malegeant [Supply Chain 2005], pp. 3.

Figure 4: Closed-loop supply chain

It is obvious that an economic system operating exclusively on the basis of closed-loop ecosystems is not realistic and in industrial systems such perfect recycling networks as those in natural ecosystems generally do not exist.[71] Still, a closed-loop

[70] Kumar/Malegeant [Supply Chain 2005], pp. 2.

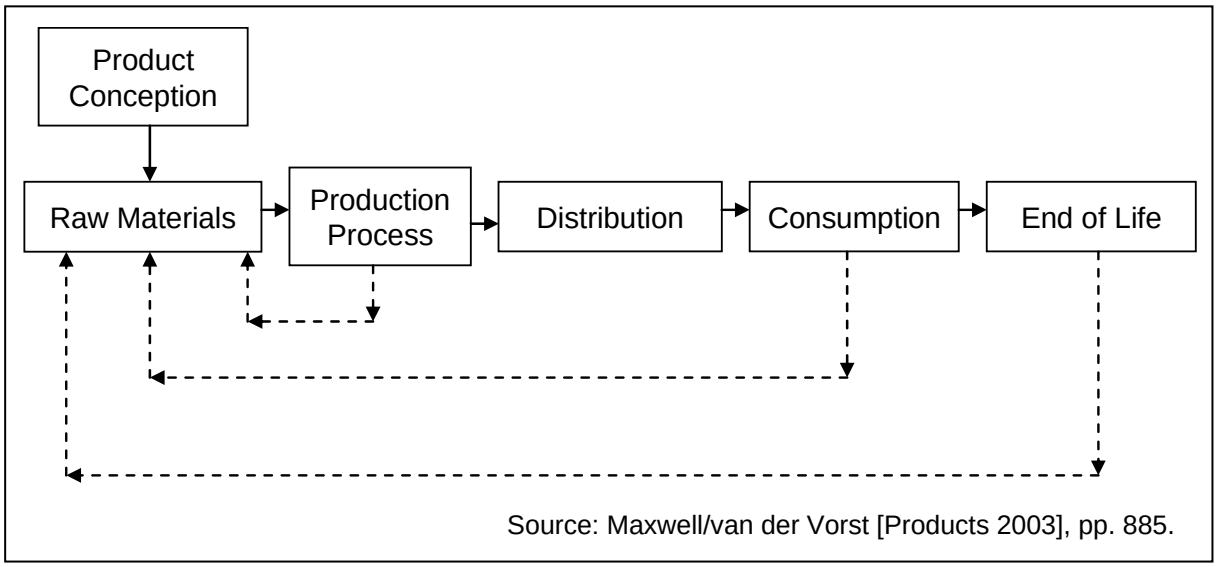
[71] Schwarz/Steininger [Network 1997] pp. 48.

supply chain or closed-loop economic subsystem aims to operate partly on the basis of an ecological system and may be able to avoid the aforementioned environmental weaknesses of an open-loop system by getting closer to a closed-loop one. This is an important enabler of sustainable development.

Contributing to sustainability by creating closed-loops is not possible on a corporate level. To reach special sustainability goals an active participation of each chain member is necessary – this is what we call a network-level approach. Not to mention, that active participation and cooperation in industrial networks may also result in important economic benefits.

4.2 Adoption of Life Cycle Analysis to evaluate outsourcing tendencies

One reason for the necessity of a network level approach of the ecological sustainability of business is the concept of life cycle assessment. The goal of the both in theory and practice fast developing method is to measure the sustainability effects of business. It places the emphasis to a product level and/or supply chain network level from a company one, since environmental effects appear at all level of production and consumption. The different product life cycle stages as it can be seen in figure 5 are the initial point for the life cycle analysis. Starting from the product conception through all life cycle stages up to the end of life have to be evaluated.



Source: Maxwell/van der Vorst [Products 2003], pp. 885.

Figure 5: Product life cycle stages

If we accept that Life Cycle Analysis (LCA) is the most developed and effective method for measuring and managing business's effects on ecological sustainability

and consider the present trends in outsourcing, than the supply chain aspect of production has to be incorporated in order to effectively reduce the sustainability impacts of products.[72] The emphasis has to be placed from a company to a production system level, since the concept of LCA suggests that the environmental concerns extend beyond an organization's own boundaries. Therefore improvements in the environmental performance can be gained through the external supply chain relationships because the supply chain includes all activities regarding the flow and transformation of raw materials and information into goods and distributing them to the end user.[73]

Although life-cycle assessment is being used for individual products or enterprises, an extension throughout the supply chain, with a focus either on individual products or on enterprises as a whole would be necessary. This requirement is tremendously important because at each stage of the chain, the manufactured product or service receives a 'backpack' full of environmental effects of production processes from earlier stages and hands the 'backpack' together with the environmental effects of its own production process over to the next stage.[74] It means that measuring sustainability on a corporate level is a useful effort in "greening" business but does not tell much about the overall sustainability effects of the products because of the long afterlife outside the company. If companies therefore concentrate only on their own impacts, large company efforts may still result in small improvements in the whole system, namely the supply chain.[75] The same effect happens if the focus on performance is addressed on a local level of scale. Focusing on a global level of scale requires a system approach since for this level all companies in a production system are responsible.

4.3 The meaning of recycling in a closed-loop-system

Another reason for the necessity of a network level thinking are the requirements for effective recycling. The waste of one production process often cannot be re-used in the same process, but maybe within another one. It means that if the waste

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72 Maxwell/van der Vorst [Products 2003], pp. 889.

73 Zhu/Sarkis [Management 2005] pp. 475.

74 Schiefer [Process 2002], pp. 199.

75 Gerbens-Leenes et al. [Sustainability 2003], pp. 232.

producing company does not have a proper re-utilization process a network is necessary by implementing integrated inter-company technologies.[76] Recycling is often an open-loop system because the products do not return to the original producer but will be used in other industries.[77] An effective solution for recycling requires cooperation among the companies of a certain supply chain and not the efforts of one single company.

Based on the advantages of handling environmental issues on a network level there are basically two different concepts in literature. One of them is green supply chain management (GSCM). The different GSCM definitions include environmental goals, e.g. reactive monitoring of general environmental practices as well as proactive practices like the Re's of environmental management.[78] The closely related concept of integrated chain management (ICM) emphasizes that an integrated supply chain aims to produce closed material cycles for the entire lifecycle and prevent the leaking of materials out of the chain so resources are being conserved and there are no rest emissions or wastes.[79] This concept takes the entire life cycle into account for reaching resource efficiency and conservation.

The second concept is industrial ecology (IE), whereby the industrial system can be a totally closed network. This closed system means that industrial ecosystems function according to the system development principles of natural ecosystems.[80] The basic philosophy in the IE approach is then to enhance the emergence of an industrial system that relies on co-operation between the actors involved, in that they use each other's waste material and energy as resources and in this way the system minimises virgin material and energy input, as well as the waste and emission output.[81] The basic difference between the two aforementioned concepts is, that while IE rather has a regional aspect, GSCM is defined by the chain and not by spatial aspects. The core idea of both concepts is that they concentrate on inter-firm relations allowing

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76 Schwarz/Steininger [Network 1997], pp. 48.

77 Fleischmann et al. [Reverse Logistics 1997], pp. 4.

78 Re's are e.g. recycling, reclamation, remanufacturing, or reverse logistics. For a detailed discussion see Zhu/Sarkis [Performance 2004], pp. 267.

79 de Groene/Hermans [Management 1998], pp. 200.

80 Korhonen [Development 2004] pp. 811.

81 Korhonen [Ecosystem 2001] pp. 254. For further aspects of industrial ecology see Ehrenfeld [Ecology 1997], pp. 90.

additional challenges but also suggesting additional risks compared to intra-firm forms of improvement.[82]

Both industrial recycling networks and sustainable supply chains are important to reach sustainability goals. These concepts highlight that making a move towards a closed-loop economy has two important aspects: a territorial and an industrial one. These two aspects are not independent from each other. In an industrial recycling network appear vertical, horizontal and also lateral forms of cooperation.[83] Vertical cooperation between companies of different production levels within the same branch or supply chain represents the industrial aspect. On the other hand a supply chain network can have a territorial aspect through cooperation among different members within one supply chain network in one given region.

The two different aspects have different advantages concerning ecological sustainability and the goal of a closed-loop economy. Thus regional recycling networks have the advantage of close physical distances what leads to better opportunities to cheap (lower transportation and coordination cost) and inter-industrial recycling. In contrast supply chain networks are complete production systems where the life cycle approach can be effectively managed. And both of the concepts can have an influential role in involving consumers into recycling activities.

Furthermore both of these network-level concepts seem to be potentially more sustainable also from an economic aspect. It is well-known that information sharing and physical flow coordination can lead to a better supply chain performance up to 35%.[84] Researches on industrial systems suggest a substantial development of industrial ecology in industrialized countries. They found that these had mainly emerged as an outcome of financial considerations or in reaction to government legislation.[85] Kalundborg area in Denmark, Styria in Austria, the Ruhr Basin in Germany, the Burnside Industrial Park in Nova Scotia, and several US and Dutch industrial areas are examples for this. Such relationships are mainly developed based on individual business interests like direct cost reductions, but also have

82 Heeres et al. [Eco 2004], pp. 987.

83 Kaluza [Verwertungsnetzwerke 2002], pp. 79.

84 Sahin/Robinson [Information 2005], pp. 583.

85 Reijnders [Choice 2000], pp. 129.

influences on indirect costs like the avoidance of waste disposal costs and taxes, lower risks, higher quality of accepted waste than primary material.[86]

5 Sustainable Supply Chain Networks as a tool for dissolving economical and ecological goal conflicts

5.1 The concept of Sustainable Supply Chain Networks

Considering that a network level approach is necessary in order to solve the basic contradiction between the functioning of economy and nature we define a sustainable supply chain network (SSCN) as: “A supply chain network which’s goals are to contribute to both economic and ecologic resource conservation, the dissolution of the contradiction between ecological and economic systems (and ecological-economic goal conflicts) and sustainable ecologic development by closing material loops and by continuously seeking the opportunities to improve both eco-efficiency and economic efficiency.”

A SSCN has two basic fields of business activities: economical and ecological activities to gain economical and ecological benefits for the members. In the area of economical activities long term agreements are concluded to integrate the activities in planning, sourcing, making and delivering goods and products along the entire supply chain. All processes have to be coordinated to improve effectiveness and efficiency of the value chain management. This causes higher security and flexibility of material- and information flows as well as better services. The establishment of win-win situations guarantees higher competitiveness and profitability for every partner. On the other hand in the area of ecological activities a common avoidance of dissipation and measures to prevent wasting materials is aspired. Furthermore a broad collection of used materials and a special waste management must be implemented. Through the recycling and reuse of used materials and products additional values can be generated. This can be intensified by common research and development to improve material efficiency. Diminishing the use of rare resources and common investment in energy efficient production equipment prevents from dependency and helps to save costs. The activities in both areas help to improve sustainability because the economic, ecologic and social needs are satisfied. Figure 6 gives an overview of economical and ecological activities in SSCN.

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86 Schwarz/Steininger [Network 1997], pp. 50.

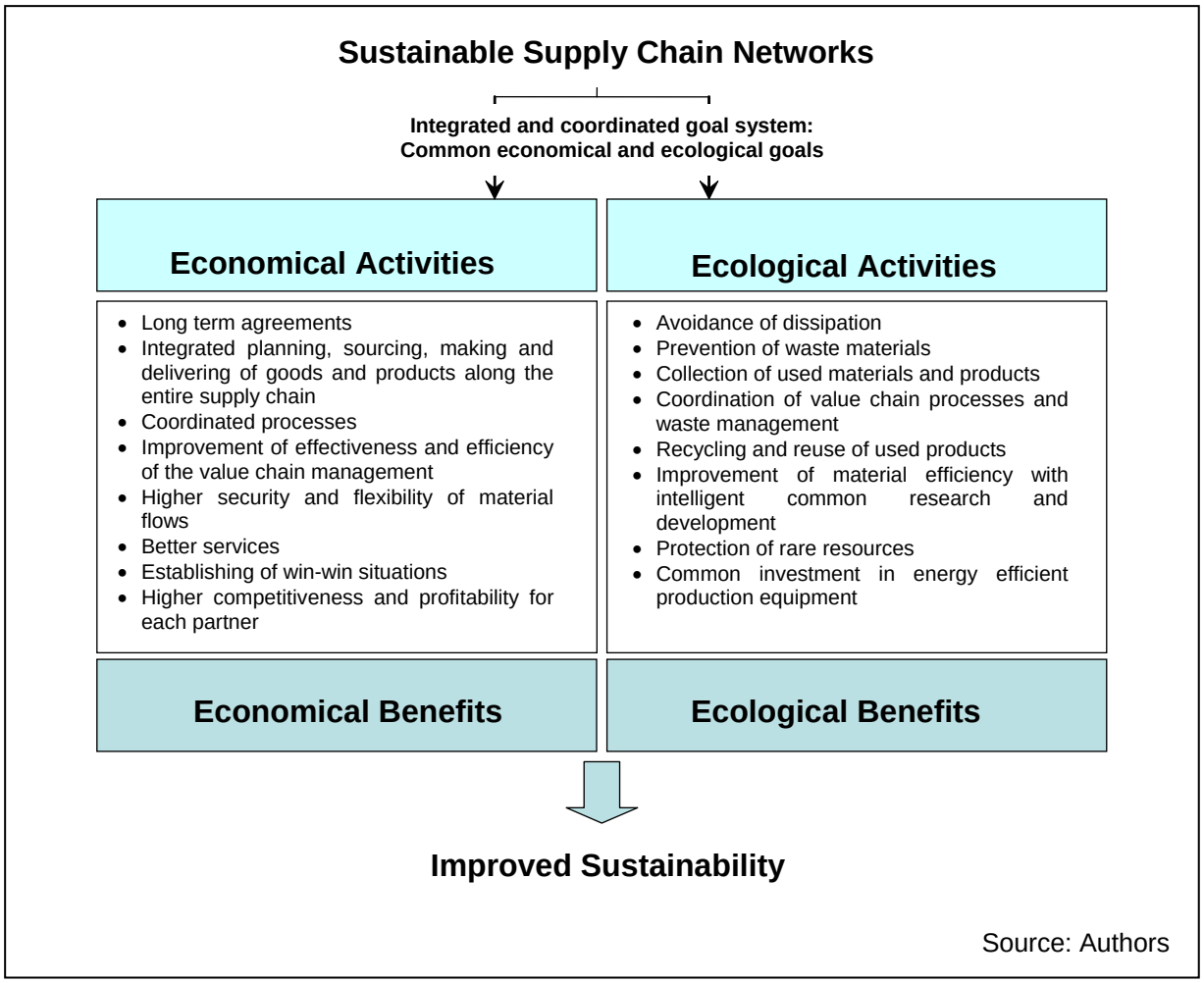


Figure 6: Improved Sustainability through Sustainable Supply Chain Networks

Regarding the sustainability interpretation we have to define our notation. Because strong or absolute sustainability[87] can not be properly measured at the moment on a corporate level[88] (and so it is with a supply chain network one) we concentrate on weak or relative sustainability,[89] namely eco-efficiency. Eco-efficiency means that we can produce the same amount of products by consuming less input from the environment. However, as long as eco-efficiency is a useful tool for improving

87 The distinction between relative and absolute sustainability results from the different opinions regarding the substitutability of natural and manufactured capital. Strong sustainability means that there is no possibility for substituting natural with manufactured capital. For the distinction between relative and absolute sustainability see Figge/Hahn [Value 2004], pp. 174, and Harte [Ecology 1995], pp. 159. For an interesting debate on substitutability see Daly [Sustainability 1997], pp. 261, Solow [Sustainability 1997], pp. 267, Stiglitz [Sustainability 1997], pp. 269, and Daly [Reply 1997], pp. 271.

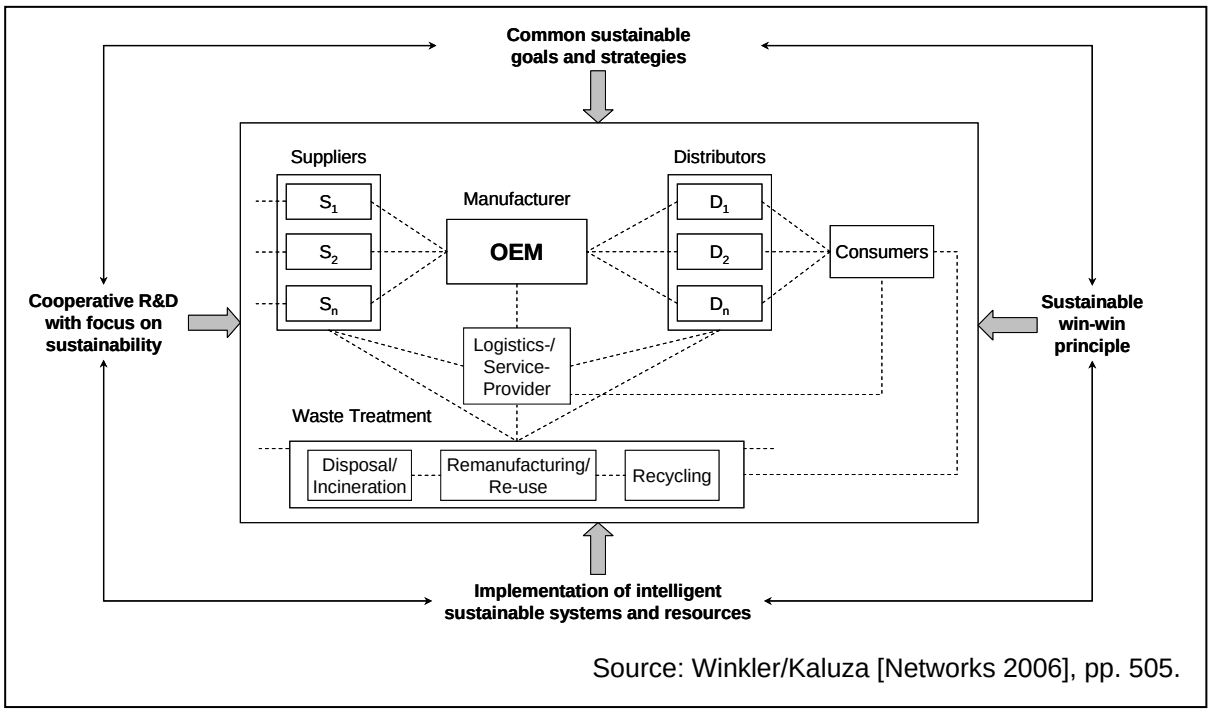
88 Handfield et al. [Supplier 2002], pp. 71, Gerbens-Leenes et al. [Sustainability 2003], pp. 243, Callens/Tyteca [Indicators 1999], pp. 43. Although microeconomic measures of absolute sustainability can be found at Figge/Hahn [Value 2004], pp. 175, the authors emphasize the numerous limits these yet face.

89 Gowdy/O'Hara [Sustainability 1997], pp. 239, Figge/Hahn [Value 2004], pp. 174, and Callens/Tyteca [Indicators 1999], pp. 43.

environmental performance and can be managed a lot more effectively on a supply chain network level than on a company one, it does not necessarily dissolve the aforementioned basic contradiction between nature and the economy. Since the dissolution requires the closure of material loops the aim of an SSCN is more than only improving eco-efficiency. It is the creation of a closed-loop system.

5.2 Organisation and structure of a Sustainable Supply Chain Network

The main principles of the SSCN should lead to a sustainable configuration of the network. Therefore, it is important to set up sustainable goals and strategies, formulate and introduce sustainable win-win relationships, implement intelligent systems and resources, as well as arrange cooperative R&D with focus on sustainability.[90] These principles interrelate with each other and have to be coordinated to reach an effective and efficient SSCN. Figure 7 shows the possible relationships between the enterprises of a SSCN. These relationships include the information-, material-, residual-, used product-, waste- and financial exchange processes among all of the companies.



Source: Winkler/Kaluza [Networks 2006], pp. 505.

Figure 7: Generic structure and principles of a Sustainable Supply Chain Network

Not only companies of an existing supply chain, but also service providers specialised in collecting, exchanging, conditioning, recycling, or eliminating used

90 Winkler/Kaluza [Networks 2006], pp. 504.

products and waste are participants of a SSCN.[91] These companies adopt duties for remanufacturing/reuse, recycling and disposal/incineration to enable a circular economy in the SSCN. Special logistics providers are integrated to manage the physical distribution and redistribution of the material flows between the participants. Together with the service providers they are also responsible for collecting, saving, and analysing waste specific information and provide them to the participants of the network.[92]

5.3 The main elements of Sustainable Supply Chain Networks

As already introduced dissolving ecological-economical goal conflicts, contributing to circular economy and sustainability requires a network-level approach. In the following we examine the concept of SSCN as an effective tool for contributing to the presented goals.

There are different supply-chain level methods (e.g. GSCM, ICM and closed-loop supply chains) in order to contribute to closed-loop economy goals and sustainability. Although as aforementioned it is probably impossible to decide if these measures are sustainable in an absolute sense, they are possibly contributors to weak sustainability and resource conservation by improved-eco efficiency and getting closer to a closed-loop economy. If they, in addition to that, also contribute to economic sustainability by improving economic performance in the same time we can call them sustainable at least in a relative sense. The same it is with production systems because a better economic and ecologic performance in the same time may also contribute to the social aspect of sustainability. This means that first of all economic success of a company contributes to the employees by getting paid for their work.

Figure 8 shows the possible elements of GSCM on a quite wide empirical and theoretical basis. The logic behind the categorization is that from a companies perspective greening a chain has to begin with greening the own company first (internal practices) and than the other participants and processes within the chain and/or network.

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91 Prahinski/Kocabasoglu [Supply Chains 2006], pp. 521.

92 Winkler/Kaluza [Networks 2006], pp. 504.

Internal environmental management	
	Commitment of GSCM from senior managers
	Support for GSCM from mid-level managers
	Cross-functional cooperation for environmental improvements
	Total quality environmental management
	Environmental compliance and auditing programs
ISO 14001 certification	
	Environmental management systems exist
External GSCM practices	
	Providing design specification to suppliers that include environmental requirements for purchased item
	Cooperation with suppliers for environmental objectives
	Environmental audit for suppliers' internal management
	Suppliers' ISO14000 certification
	Second-tier supplier environmentally friendly practice evaluation
	Cooperation with customer for eco-design
	Cooperation with customers for cleaner production
	Cooperation with customers for green packaging
Investment recovery	
	Investment recovery (sale) of excess inventories/materials
	Sale of scrap and used materials
	Sale of excess capital equipment
Eco-design	
	Design of products for reduced consumption of material/energy
	Design of products for reuse, recycle, recovery of material, component parts
	Design of products to avoid or reduce use of hazardous of products and/or their manufacturing process

Source: Zhu/Sarkis [Performance 2004] pp. 268

Figure 8: Categories of Green Supply Chain Management in literature

According to a process based approach the major subcomponents of greening on a supply chain level are inbound logistics (which includes procurement), materials management, outbound logistics, packaging, and reverse logistics issues.[93] In the following we also follow a process-based view by introducing the basic SSCN elements: sustainable planning, sustainable purchasing, sustainable production process management (forward flow and recycling), and sustainable distribution (both forward and reverse). When doing so we include both the product and the organizational perspective, of sustainable development.[94] The product perspective is applied at the design stage whereas the organizational perspective is applied to

[93] Sarkis [Practices 1998], pp, 162.

[94] Chouinard et al. [Reverse Logistics 2005], pp. 107.

ensure effective and efficient activities related to the recovery and processing of recycled products.

5.3.1 Sustainable planning

If we take a look at the process of production, sustainable practices are to a high extent determined by planning. Within the SSCN, two planning levels have to taken into account.[95] The first planning level corresponds to the network-level, the second to the enterprise-level. To run a circular economy the companies formulate environmental goals, strategies, measures and measurement principals for co-operation on the network-level in common, but the companies remain legally and economically independent, making their own strategic and operational decisions influenced by the network strategies.

During the product conception and design most of the environmental, social and economic cost factors are determined even up to 80%.[96] Environmental excellence starts during initial design, the environmental impact of a product is predominantly fixed at the product and process design phase.[97] Also, eco-design determines the whole value chain, which describes how the supply chain is managed. This value chain can be described by the concept of *operational life cycle* which includes procurement, production, distribution, reverse logistics and packaging.[98] Furthermore, the design of products and processes directly influences production process efficiency, packaging, transportation, durability, reliability, subsequent disassembly, and other functions and performance criteria.[99] Sustainable recycling is also told to be strongly dependent on product design – since it slows loss of quality by products and materials.[100]

The role of eco-design or green design is to design and develop products in a way that environmental criteria are taken into consideration equal to economic ones.[101] It

95 Winkler/Kaluza [Networks 2006], pp. 505.

96 Maxwell/van der Vorst [Products 2003], pp. 889.

97 Zsidisin/Hendrick [Purchasing 1998], pp. 314.

98 Sarkis [Management 2003], pp. 398.

99 Zsidisin/Siferd [Purchasing 2001], pp. 67.

100 Reijnders [Choice 2000], pp. 131.

101 de Groene/Hermans [Management 1998], pp. 202.

is an extension of quality focus and should incorporate the ideas of design for ease of disassembly, design for disposability that will not have a negative effect on the environment, design to eliminate harmful processes in manufacturing, design for ease of distribution and return, elimination of many or all hazardous materials used, design for durability and reliability and design for customer success.[102]

As already mentioned one reason for the shift in thinking from a corporate to a network level is LCA. The relationship between the eco-design and LCA is not clear in literature. According to certain authors[103] eco-design does not include LCA while others[104] state that eco-design's goal is to consider the complete product life cycle when designing environmental aspects into a product. A research on 15 eco-design tools found that eight of them had a life cycle perspective.[105]

In our opinion eco-design without life cycle analysis is close to the traditional view of manufacturing which means that the product is no longer important after leaving the company.[106] Eco-design does not involve a systematic chain analysis and it does not provide possible solutions for improvement in the whole chain.[107] Although it involves environmental considerations which can effectively result in better ecologic performance it does not follow the way of a product from the raw material to the after-consumption phase. Therefore it does not help to solve the contradiction between nature and economy since it does not necessarily results in closed economic loops.

All parties in the life chain of a product (or more products) depend on each other in the implementation of environmental and economic improvements within the chain.[108] Connecting eco-design with life cycle analysis can theoretically result in a lot better economic and ecologic performance on an SSCN level. Through information sharing and cooperation it is possible to follow a product's and other material's whole lifecycle and as a consequence the chances of economic usage of wastes as raw materials are higher. On the other hand total cost assessment (TCA) is also very

102 Zsidisin/Siferd [Purchasing 2001], pp. 67.

103 de Groene/Hermans [Management 1998], pp. 202.

104 Sarkis [Practices 1998], pp. 160, van Weenen [Product 1995], pp. 96.

105 Byggeth/Hochschorner [Ecodesign 2005], pp. 5.

106 Sarkis/Rasheed [Manufacturing 1995], pp. 21.

107 de Groene/Hermans [Management 1998], pp. 202.

108 de Groene/Hermans [Management 1998], pp. 200.

important to carry out already in the begin of the designing phase if the proposed eco-design is cost-effective in order to make a decision towards economic sustainability.[109]

One potential reason for the fact that life-cycle analysis is not necessarily included in eco-design on a single corporation level is that individual manufacturing processes cannot be considered in isolation. A process that produces relatively large quantities of waste that can be used in another process may be preferable to one that produces smaller amounts of waste for which there is no use.[110] This contradiction can be dissolved by analysing and managing sustainability on a supply chain network level. As more and more companies join the chain network and use more and more wastes as raw materials it becomes easier to follow the material flow a lot more precisely and decide weather the emerging waste really is waste or valuable raw material. There is also a better chance of measuring and managing economic aspects. It means that applying eco-design on a supply chain level and connecting it with LCA can provide effective solutions to reach closed-loop economy goals.

A similar approach is *Sustainable Product and Service Development* (SPSD) that contains sustainability issues which are not included in eco-design in its present form. It is defined as a process of manufacturing products and/or services in a more sustainable way during their entire lifecycle.[111] This is from the product conception to end of life. The products and/or services are developed to be more sustainable. This means in the known Triple Bottom Line context balancing economic, environmental and social aspects. In other words, with the help of SPSD superior products and/or services that fulfil traditional criteria as well as sustainability requirements can be developed. The Sustainable Product and Services pyramid illustrates the relationship of SPSD to other environmental planning methods as it can be seen in figure 9.

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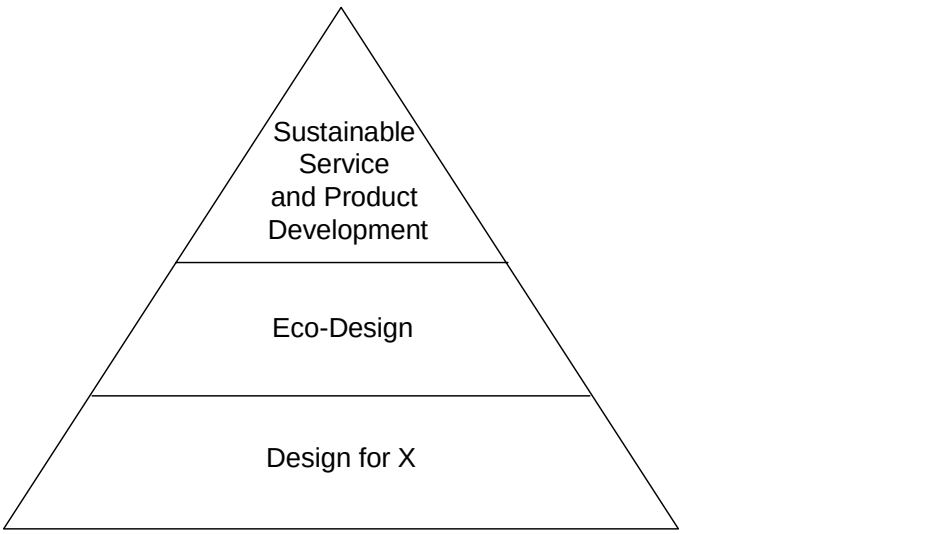
109 Hur et al. [Green Productivity 2004], pp. 675.

110 Sarkis/Rasheed [Manufacturing 1995], pp. 20.

111 Maxwell/van der Vorst [Products 2003], pp. 884.



Source: Maxwell/van der Vorst [Products 2003], pp. 884.

Figure 9: The sustainable product and services pyramid

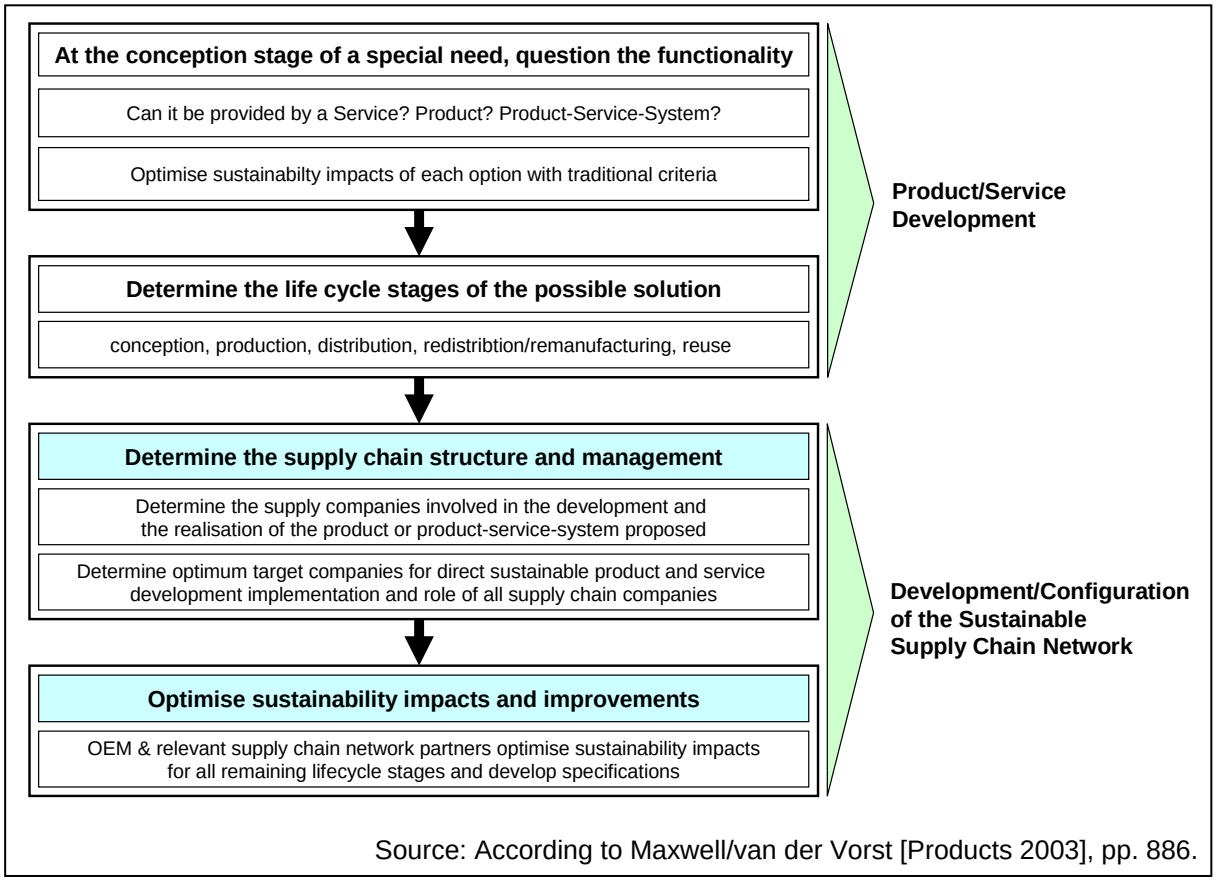
The Design for '*X*' approaches focus on specific areas, e.g. design for disassembly, or recycling, etc. A more sustainable result in theory can be reached by including the concepts at the top of the pyramid in the SPSD method. If it does not happen specific environmental impacts of the product and/or service may be minimised, but greater opportunities for producing a more sustainable product and/or service will not be realised.[112] SPSD also incorporates the Product Service Systems (PSS) concept which is about shifting the focus of the design away from producing products to providing a function and determining whether the function can be provided by a service, a product or some combination of it. This approach reduces the volume of products manufactured while maintaining or increasing profits for the company through service provision what results in environmental benefits.[113] Questioning the necessity of a product and the consideration of alternative ways to meet a functional requirement is an essential component of SPSD since it is able to significantly reduce the burden on natural resources.

SPSD starts with a product life cycle analysis within the conception stage. One of the initial steps is to consider if the functional requirement can be met with a product or a service. In other words the sustainability impacts of these options can be optimised while also considering traditional criteria. The application of the method may result in a product not being produced at all since it is more sustainable and feasible to meet

[112] Maxwell/van der Vorst [Products 2003], pp. 884.

[113] Maxwell/van der Vorst [Products 2003], pp. 885.

the required functionality by a service or with a different combination of products and services where services play a more important role. After this decision a supply chain analysis are necessary. This means that the level of analysis shifts from a company to a supply chain network one. After the analysis the implementation of SPSD at a company level (by the OEM) takes place. The OEM is the one who has control over the main life cycle phases and involves the relevant supply chain members in the process.[114] Figure 10 shows the different steps of integrating the SSCN into the SPSD concept.



Source: According to Maxwell/van der Vorst [Products 2003], pp. 886.

Figure 10: The SPSD development and the configuration of a SSCN

Trust,[115] cooperation and the setting of common network level goals[116] within the network plays an important role at the planning stage. Therefore cooperation demands a subject-oriented inter-company dialogue.[117] As aforementioned information sharing is a basic enabler for improving the supply chain performance.

114 Maxwell/van der Vorst [Products 2003], pp. 886.

115 Kaluza [Verwertungsnetzwerke 2002], pp. 94. Regarding trust see also at Kreikebaum [Ecology 1998], pp. 71, and Zabel [Industriesymbiosen 1998], pp.150.

116 Kaluza [Performance 2004], 314.

117 Schwarz/Steininger [Network 1997], pp. 52.

The two basic alternatives for the creation of the proper flow of information are the centralized and the decentralized approach.[118] Within the centralized approach the information flow and communication are coordinated by a central institution, e.g. the focal company of the supply chain. No information redundancy is one benefit of this approach since one single company is responsible for the information storage. Examples for that are the food supply chains in the Netherlands and sectors with great differences in the market power of chain enterprises. When communication is based on common agreements and direct communication between the individual enterprises there is a decentralized approach. Short transmission ways as well as flexible data structures are the main advantages for the supply chain. Danish meat chains with a system of discussion groups on different levels of chain management are a good example for this approach. For improving the data handling considering environmental issues supplier trainings, workshops, environmental forums and environmental advisory groups can be useful.[119] The fact, that the different supply chains are linked within the same network possibly helps better communication, ensures cooperation and realizes the potential of systematic resource recovery among actors and also reduces transaction costs (related to information sharing and cooperation).[120] Although it is a special situation it can be suggested that having one organization responsible for information flow and seeking cooperative opportunities can effectively help to dissolve the informational barrier.

One tool for building out trust within a network is the construction of atmosphere, which influences the further development of the network. The creation of atmosphere happens by the establishment of communication forums, inter-industrial technology transfers, enhanced effort to find uses for the ‘good’ of waste, enhanced security within the network and the support of marketing efforts of individual firms by the network.[121] It is tremendously important for the network to introduce a security system. This system rewards cooperating enterprises and punishes defecting ones. The evaluation of the cooperative manner should be done by all of the members of the network. A good example for the relevance of atmosphere is the Kalundborg structure, where in the 29 years of evolutionary formation (1961-1989) of the network

118 Schiefer [Process 2002], pp. 200.

119 Lippmann [Management 1999], pp. 178.

120 Zhu/Cote [Management 2004], pp. 1031.

121 Schwarz/Steininger [Network 1997], pp. 53.

only ten recycling relationships were developed, while after the “discovery” of the structures another six waste relationships developed within only 5 years (1990-1994).[122]

To realize such common tools and set common goals the role of the OEM is vital since the OEM has the control over product/service design and specification which also determines the activities of other companies within the supply chain.[123] Also, OEMs producing final products are much more aware of green pressures since consumer attention is almost fully focused on them and not on part manufacturers.[124] Based on case studies carried out in the supermarket industry, aerospace industry in the UK and the food retail industry in Japan environmental supply chain dynamics can also play an important role. When outer environmental pressures on costumer firms pairs with a relatively high power of these firms within the supply chain a phenomenon where environmental innovations diffuse from a customer firm to a supplier firm appears. This environmental innovation can be a product, service, process, technology or technique developed to reduce environmental impacts.

The role of the introduction of environmental awareness to customer requirement by SPSD is also important,[125] because the alignment of lifestyles is also necessary to reach ecological sustainability.[126] Since municipal solid waste (MSW, commonly known as trash or garbage), is one of the most prevalent waste types (e.g. in 2000 the USA generated approximately 232 million tons of MSW, primarily in homes and workplaces, which means an increase of nearly 160% since 1960 and approximately 4.5 pounds of waste per day or about 0.8 tons per year),[127] closed-loop economy goals are not possible to achieve without involving consumers.

There are different facts that show that environmental product stewardship can effectively impact consumer behaviour. E.g. most consumers are green in their intentions but do not have enough information about the environmental performance of products to follow their environmental conviction. Also, consumers buying green

122 Schwarz/Steininger [Network 1997], pp. 54.

123 Maxwell/van der Vorst [Products 2003], pp. 889.

124 Hall [Dynamics 2000], pp. 459.

125 Kaebernick et al. [Product 2003], pp. 462.

126 Zabel [Industriesymbiosen 1998], pp. 155.

127 Kumar/Malegeant [Supply Chain 2005], pp. 2.

products are characterized by having significant knowledge about the state of nature, acquired from education or experience.[128] Furthermore, many consumers usually have a lack in resources or time to make decisions on proper information and there is a growing confusion among them with green marketing.[129] Providing the necessary information and helping the consumer, environmental product-stewardship is an important enabler of the shift towards a closed-loop economy since it indicates consumer needs for environmental friendly products, provides proper information for consumers about the environmental aspects of products, and force the consumers willingness to return used products in such a form that it is possible to recycle them. Another important role of environmental stewardship is that it aids the improvement of ecological and economical performance by influencing employees - who are also consumers - environmental awareness. More environmentally conscious consumers mean more environmentally conscious employees and help to avoid such problems that employees in different industries may handle waste materials careless which make recycling and the closure of loops more expensive or even impossible.[130] On the other hand not only consumer willingness but also consumer opportunity is important. If environmental information concerning possible consumer environmental actions (e.g. on recollecting points) is not provided and reverse logistic channels and infrastructure regarding consumers are not built out consumer willingness will not be able to contribute sustainability and closed-loop economy goals.

Regarding the planning of resource use two aspects of quality are of major importance: whether or not significant losses of irretrievable material do occur and whether the product associated wastes allow recycling in the physical sense to build up a closed loop economy, which means that recycling is possible over and over again, each time ending up in the applications of the same physical character. In case of no significant loss of irretrievable material and the possibility of closed loop recycling both renewable and non-renewable natural resources are appropriate resource bases. When these conditions are not met and deterioration happens, only renewable materials should be considered.[131]

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128 Soler [Buying 1996], pp. 279.

129 Hall [Dynamics 2000], pp. 458.

130 de Groene/Hermans [Management 1998], pp. 209.

131 Reijnders [Choice 2000], pp. 125.

The Nordic project for environmentally sound product development has developed methods, data tools and guidelines for sustainable product development. It is based on three tools for evaluating customer requirements, economy and environmental performance of products in a life cycle perspective: Quality function deployment (QFD), life cycle cost accounting (LCC), and environmental life cycle assessment (LCA).[132] For reaching sustainability it is important to include product performance and cost analysis in SPSD since sustainability includes economic, ecologic and social aspects. Although environmental performance is even more important, consumer behaviour is first of all determined by product quality and price. If an ecologically more sustainable alternative is more expensive or of weaker quality economic sustainability may be lost which later results in loosing also the ecological one.

The length of product life cycle is important from the aspect of ecological planning and sustainability. Products of longer life basically mean less renewing which results in lower burden on natural resources.[133] Since the length of life cycle is also a question of product reliability, SSCNs must be able to estimate the reliability of their products at any phase of product life cycle and have to be capable of designing easily repairable products in order to maintain this reliability at a desired level.[134] The costs generated by maintenance activities in order to achieve a high reliability can be reduced by using valorised materials of good quality and at lower cost. Although it is technically possible to produce more and more durable goods, it does not seem to be enough to secure resource conservation itself, since the life cycle of most products is getting even shorter in practice. One reason for that is the so called moral aging. To overcome this problem companies are forced to meet customer requirements.[135]

Further aspects of ecological design in order to reduce negative environmental effects are reducing the consumption of non-renewable resources, integrating valorised components, reducing the variety of components, adopting modular design, shifting to standardized materials, reducing manual adjustments in order to decrease the risk of errors or to favour recyclable materials. These measures are

132 Hanssen [Product 1999], pp. 28.

133 Renner [Economy 2004], pp. 105.

134 Chouinard et al. [Reverse Logistics 2005], pp. 107.

135 Kaebernick et al. [Product 2003], pp. 462.

important to introduce in order to simplify and add value to activities related to production, after-sales service, recovery and processing while also meeting quality standards.[136]

5.3.2 Sustainable purchasing

Environmental purchasing is the involvement of purchasing in supply chain management activities in order to aid recycling, reuse, and resource reduction.[137] According to a more detailed definition environmental purchasing (EP) for a company is the set of purchasing policies used, actions taken, and relationships formed in response to environmental concerns. These concerns are related to the acquisition of raw materials, including supplier selection, evaluation and development, suppliers operations, in-bound distribution, packaging, recycling, reuse, resource reduction, and final disposal of the firm's products.[138]

Purchasing methods and purchasing managers have both direct and indirect effects on the environment.[139] Direct effects are related to waste during storage, transportation, processing, use or disposal and indirect to the waste streams generated when suppliers produce them. They have a strong influence on waste and its disposal and recycling, energy and material resource use and emissions.[140] They can also definitely contribute to environmental performance by environmentally friendly packaging, buying elements after life-cycle analysis, contributing to reuse, recycling and resource reduction by using early supply design involvement.[141] Six possible dimensions of environmental purchasing are: purchasing recycled packaging, purchasing packaging that is of lighter weight, using a life-cycle analysis to evaluate the environmental friendliness of products and packaging, participating in the design of products for disassembly, recycling and reuse, asking suppliers to

136 Chouinard et al. [Reverse Logistics 2005], pp. 107.

137 Carter et al. [Purchasing 2000], pp. 220.

138 Zsidisin/Siferd [Purchasing 2001], pp. 69.

139 Handfield et al. [Supplier 2002], pp. 71.

140 Zsidisin/Siferd [Purchasing 2001], pp. 62.

141 Carter et al. [Purchasing 2000], pp. 222.

commit to waste reduction goals and participating in the design of products for recycling or reuse.[142]

Considering environmental purchasing significantly alters the purchasing process. First, alignment with other corporate objectives has to be ensured (e.g. Sony's procurement policy, which promotes quality, cost, delivery, service, and the environment). This results in a new economically justified and integrated green purchasing process. The most important change occurring compared to the traditional purchasing process is the informational need of environmental purchasing because of integrating environmental issues.[143]

According to an empirical research among firms applying environmental aspects at purchasing decisions none of them managed to develop a systematic method for integrating environmental measures into supplier evaluation and selection decision since it is very hard to measure the greenness on a corporate level.[144] By the authors interviewed managers agreed that more information were needed regarding measures and the definition of a green supplier. The most important environmental measures according to them are shown in figure 11.

Top 10 – most important environmental criteria	Top 10 – most easily assessed environmental criteria
1. Public disclosure of environmental record	1. ISO 14000 certified
2. Second tier supplier environmental evaluation	2. Ozone depleting substances
3. Hazardous waste management	3. Recyclable content
4. Toxic waste pollution management	4. VOC content
5. On EPA 17 hazardous material list	5. On EPA 17 hazardous material list
6. ISO 14000 certified	6. Remanufacturing/reuse activity
7. Reverse logistics program	7. Returnable or reduced packaging
8. Environmentally friendly product packaging	8. Take back or reverse logistics
9. Ozone depleting substances	9. Participation in voluntary EPA programs
10. Hazardous air emissions management	10. Public disclosure of environmental record

Handfield et al. [Supplier 2002], pp. 78.

Figure 11: Top 10 criteria for supplier environmental performance

It seems that there are basically two main barriers of ecologic purchasing. These are managerial perceptions and the aforementioned lack of information and objective measurement opportunities of suppliers' environmental performance.[145]

142 Carter et al. [Purchasing 2000], pp. 225.

143 Handfield et al. [Supplier 2002], pp. 73.

144 Handfield et al. [Supplier 2002], pp. 76.

145 Carter et al. [Purchasing 2000], pp. 220.

As we can see on table 9 there are supplier activities connected to recycling which are relatively easy to measure, e.g. recyclable content, remanufacturing/reuse activity, returnable or reduced packaging, take back or reverse logistics. Furthermore there are also such numerous measures on a supply chain level.[146] Although activities connected to recycling are not held extremely important among the criteria of supplier environmental performance, their role is different on a chain network level. Without lessening the role of reduce we emphasize that, as already quoted in a different context, a process that produces relatively large quantities of waste that can be used in another process may be preferable to one that produces smaller amounts of waste for which there is no use.[147] Therefore recycling gains a vital role on a supply chain network level where information is accessible on the further way of waste. Here recycling and procurement supporting it are effective tools of getting closer to a circular economy by enabling the closure of supply chain processes.

Regarding the preferential role of recycling, procurement supporting recycling and the managerial perceptions concerning green procurement on a chain level we emphasize the role of an information centre to overcome these barriers. Here relevant information on raw materials, recycling opportunities within the network and suppliers can be gathered and made accessible to decision makers. In connection with procurement the information centre is also supposed to have proper information on supplier's and procured product's hazardous material data and suppliers and their products environmental evaluation by third organizations since these are also major measures of environmental friendliness.

5.3.3 Sustainable production processes

Regarding production processes, a sustainable supply chain network has to involve both forward (traditional) and reverse (recycling) production processes.

5.3.3.1 Forward production processes

As already mentioned greening the own company,[148] e.g. the OEM, is a key factor in greening a supply chain network. However, the implementation of environmental

146 Kaluza [Performance 2004], pp. 322.

147 Sarkis/Rasheed [Manufacturing 1995], pp. 20.

148 Zhu/Sarkis [Performance 2004], pp. 267.

management activities with a prime focus on the society's environmental interests besides business management ones with a prime focus on the enterprises economic interests results in major increases in management complexity. It increases the need for an integrated view of supply chains in business management and the incorporation of qualitative and soft criteria into monitoring and evaluation routines of management activities.[149]

Although a supply chain network level is necessary to implement these measures effectively, e.g. to decide weather waste really is waste, a company level is important especially to reduce waste. Source reduction activities include input changes, operational improvement that leads to loss prevention, production process changes, product reformulation, inventory control, and administrative and organizational activities such as training.[150] In order to properly implement greener production methods organizations have to establish strategies, structures, and systems to effectively help managers to meet environmentally responsible decisions without sacrificing economic interests. Therefore it is also important to integrate the manufacturing strategy of a firm within the overall business strategy in order to gain competitive advantage.[151]

One tool for establishing these structures is to implement an environmental management standard (ISO 14001 or EMAS). Although the implementation itself does not secure greener operations of an organization it places environmental protection within the corporate structure on a strategic level and may contribute to the implementation of tools like energy rationalization, waste minimization, cleaner technologies, lifecycle analysis, environmental indicators, transforming of distribution systems on the basis of environmental aspects, transforming of transporting systems on the basis of environmental aspects, or the forming of environmental friendly offices. These tools are not only important from an ecological aspect, but can also result in a better economic performance, since almost all of them can be profitable. The ones connected to resource conservation can already be remunerative in the very short run,[152] so they are able to contribute to economic resource conservation.

149 Schiefer [Process 2002], pp. 198.

150 Sarkis/Rasheed [Manufacturing 1995], pp. 18.

151 Sarkis/Rasheed [Manufacturing 1995], pp. 22.

152 Freimann/Walther [Systems 2001], pp. 97.

Implementing environmental standards may also result in a better company image since as corporate environmental protection is institutionalized and a standard is gained, the environmental consciousness of the company becomes more visible for the public.

Other management tools like total quality management (TQM) and just in time (JIT) also play an important role in supply chain network waste reduction. Besides its direct implications TQM also contributes indirectly to waste defect reduction by minimizing the need for rework and consumption of additional energy while possibly providing also such economic benefits as less work, energy and time. JIT can aid reduction by reducing deterioration regarding the fewer materials held in inventory. Additive fabrication process databases helping identifying less hazardous substitutes and waste monitoring technologies can also be useful tools for reduction.[153] Besides the potential advantages JIT also can have negative effects on the SSCN performance which have to be taken into consideration when creating an SSCN. Emissions through increased transport activity mean extra pollution and extra costs because of the tendency of growing fuel prices.[154] One fact that qualifies this statement is the tendency that many suppliers settle their production facilities near the OEM in order to guarantee the security of supply.

Remanufacturing which means the repair, rework, or refurbishment of components and equipment for either sale or internal use, also has to be considered when greening the production process. The process of remanufacturing includes steps like the disassembly of components, inspection and testing of the remanufacturable components, incorporation of any new improvements, and reassembly of components with newer systems.[155] It secures advantages like reducing both the consumption of raw materials and pollution. Remanufacturing has to be considered and can be carried out if the following criteria are met: the product and/or process technology is stable, the product has a "core" that can be the basis of the restored product, a continuing supply of such cores is available, the core is capable of being disassembled and restored to its original condition, the product is one that is factory built rather than field assembled and the recoverable value added in the core is high

153 Sarkis/Rasheed [Manufacturing 1995], pp. 18.

154 Heintze [Krise 2005], pp. 34.

155 Sarkis/Rasheed [Manufacturing 1995], pp. 18.

relative to both its market value and its original cost.[156] The examples of corporations like Xerox prove the economic rationality behind remanufacturing.[157]

5.3.3.2 Reverse production processes

Achieving circular economy goals also requires reverse production processes namely recycling. Recycling has strong ecological and economical advantages. It is able to reduce both waste and the demand for virgin raw materials. It means a reduction of waste disposal and raw material costs, and also both supply and disposal risk.[158] Furthermore, the use of recycled material can result in the reduction of energy costs in transforming inputs into products[159] and the same can be told in the case of pollution.[160] The major elements influencing the waste which is generated through the supply chain are reduction, repair and reuse, refurbishing, cannibalization, remanufacture, recycle, and disposal alternatives.[161] Although there are important differences among these processes we do not make a distinction here and write about recycling although in most cases also considering reuse and remanufacturing, since the basic concept behind all of the tools is to gain economic and ecological advantages by transforming “valueless wastes” into valuable raw materials.

Except reduction, all of these elements are end-of-pipe solutions. Although the tools are basically ordered of least preferable environmental impacts[162] we think that it cannot be said that one is preferable to the others on a chain network level. It is true that reduction is basically demanded by each type of manufacturing, but different products and production systems enable the application of different end-of-pipe methods. On a supply chain level processes which produce a large amount of waste can be preferable to others which process a lot less, because the larger amount of waste can be useable as raw material in other production processes. It means that if a supply chain is properly organized, methods which are considered end-of-pipe on an individual firm level can be more effective than resource and waste reduction.

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156 Sarkis/Rasheed [Manufacturing 1995], pp. 19.

157 Kaluza/Blecker [Entsorgungslogistik 1996], pp. 48, Blecker [Kreislaufwirtschaft 1998], pp. 117.

158 Schwarz/Steininger [Network 1997], pp. 55.

159 Renner [Economy 2004], pp. 105, Schwarz/Steininger [Network 1997], pp. 48.

160 Reijnders [Choice 2000], pp. 126.

161 Kumar/Malegeant [Supply Chain 2005], pp. 3, Sarkis [Management 2003], pp. 399.

162 Sarkis [Management 2003], pp. 199.

The territorial aspect of recycling

The territorial dimension of recycling is at least as important as the industrial (chain network) one. First, an ecologically optimal industrial system can only be defined in connection with regional capabilities, just like an economically optimal one.[163] Furthermore, the huge amount of materials which have to be transported and the ecological and economical costs connected to these processes result that physical distance has an important role in both the ecological and economic effectiveness of the process. The already mentioned regional recycling networks are good examples for the importance of the territorial aspect. In the regional recycling network of Styria 77,5% of the more than 1 million tons of waste are recycled within the network.[164] Rising energy prices also highlight the importance of the territorial aspect when transporting such an amount of materials.

Close physical distance has some other advantages, e.g. it enables to start a project with utility sharing, which reduces the initial investment and is a lot less risky in an economic sense compared to energy, water and material waste exchanges.[165] Furthermore it helps to create resource exchanges since the greater the initial cost is the less likely firms are acting voluntarily,[166] which is essential in order to close the loops of an industrial system. Researches on the industrial networks of Kalundborg and Styria found that each of the two developed around one or more focal enterprises.[167] This fact also highlights the relevance of the territorial aspects since these companies produce a relatively large amount of waste which must be transported.

Tools for creating effective closed-loop industrial networks

Both the industrial aspect, cooperation within a supply chain network in order to create the preconditions of recycling, and the territorial aspect, close physical distance, should be taken into consideration when deciding about effective recycling opportunities. In order to create closed-loop industrial networks there are different

163 Wallner [Ökologie 1998], pp. 94.

164 Posch et al. [Verwertungsnetz 1998], pp. 212.

165 Heeres et al. [Eco 2004], pp. 994.

166 Granek/Hassanali [Sustainability 2005], pp. 7.

167 Schwarz/Steininger [Network 1997], pp. 50.

tools to develop. Such enabling and contributing tools sometimes already exist and beneficial energy, waste and material exchanges among several companies, which can help to dissolve goal conflicts. At the beginning it may occur that companies are not willing to implement more sustainable tools since they find them financially risky. Already existing successful examples can introduce the potential ecological and economical benefits towards third parties and can prove to be strong incentives to participate in such a network. If we do not have such relationship in place, another tool for encouraging companies to participate can be the presentation of other already existing supply chain methods by the representatives of the participants. This can also improve the chance of a successful project by sharing already existing experiences and showing fix and already functioning patterns.[168]

A proper and cooperative political environment and the active participation of non-governmental organization (NGO) may also be of great importance for solving economical-ecological goal conflicts and creating sustainable business networks.[169] Introductions and referrals by established business networks, i.e. industry associations, in combination with joint marketing activities of consultants are effective strategies for gaining client acceptance.[170] Also, a strategic alliance with an NGO (first of all an ecologic group) has several important advantages. It creates a green image, generates more profits, and outsourcing the collection activity within the closed-loop supply chain allows the company to focus on its core business which is the key to higher yields.[171] Therefore an eco-partner and/or a service provider can take care of the logistics of collecting, and the supply chain companies can focus on the end users for the resulting materials and products.[172]

Because of the supply chain network and territorial aspect of recycling and the necessity of the integration of these two it is important to create integrated information and coordination organs. One tool enabling this integration can be a regional recycling agency.[173] Although the concept basically has a regional aspect it

168 Heeres et al. [Eco 2004], pp. 993.

169 Korhonen [Ecosystem 2001], pp. 255, Heeres et al. [Eco 2004], pp. 991.

170 Granek/Hassanali [Sustainability 2005], pp. 7.

171 Kaluza/Blecker [Wettbewerbsstrategien 2000], pp. 27.

172 Kumar/Malegeant [Supply Chain 2005], pp. 5.

173 Schwarz [Unternehmensnetzwerke 1994], pp. 168.

can be extended. First, it is important to set common supply chain network level goals.[174] Afterwards the compatibility of the different information systems has to be guaranteed. Therefore already existing production planning and control systems (PPS) have to be connected on a network level,[175] and have to be extended about components which handle recycling issues. Such systems are called production and recycling planning and control systems (PRPS).[176] Since the goals of a PRPS are not necessarily measurable in monetary terms it is important to formulate backup-goals, first of all time or quantity goals.[177]

Afterwards, if the focal enterprises of one region have proper supply chain-level data on raw-material needs and emerging waste based on their supply chain-level PRPS systems, they can be connected through an agency, which means the connection of the territorial and industrial dimensions of recycling. This results in better environmental and economic performance because of better information flows, better cooperation and new long-range relationships, improved chance of inter-industrial recycling and technology transfer relationships as well as increased competition because of the larger size of the market of wastes.

However, the necessity of such a central organ is also a question of the size of the network.[178] As long as the task of institutionalization in smaller networks can be fulfilled by the companies themselves, the more companies are reciprocally bound to each other, the more an individual firm is deterred from bearing costs primarily benefiting other companies. In larger networks a separate information and coordination office is advisable in order to reduce conflicts and also transactional costs.[179] The central organ can be an effective tool in order to overcome the often existing informational deficiencies within a regional recycling network.[180] Because of the possible diversity of companies involved in the network, which is a result of the territorial aspect of recycling, other outer organs and tools, e.g. an investment

174 Kaluza [Verwertungsnetzwerke 2002], pp. 90.

175 Kaluza [PPS-Systeme 2001], pp. 20.

176 Kaluza et al. [Konzeption 2001], pp. 47.

177 Kaluza [Verwertungsnetzwerke 2002], pp. 94.

178 Kreikebaum [Ecology 1998], pp. 63.

179 Schwarz/Steininger [Network 1997], pp. 54.

180 Schwarz [Verwertungsnetze 1998], pp. 22.

recovery company,[181] internet databases, waste stock exchange and recycling databases with real-time access[182] can also mean an effective solution for coordination tasks concerning recycling.[183]

Service providers like fourth party logistic providers and internet can also be contributing tools for information exchanges. First of all in a territorial and not in a chain aspect. A good example for that is Throwplace.com, an eco-non-profit organization to connect both businesses and donors. On its website recycling and reuse are promoted and facilitated by providing a nation-wide venue for everyone to post and find excess inventory and possessions. Advantages are that business subscribers do not have to build out their own closed-loop networks, can focus on their core competencies, reduce collection costs and improve their green image by being listed in the Business Directory showing that they are environmentally responsible and community-minded.[184]

5.3.4 Sustainable distribution and redistribution

Making distribution more sustainable demands the analysis of new aspects, namely the state of the traditional distribution strategy and reverse distribution or reverse logistics.

5.3.4.1 Transportation

Regarding the forward distribution flow the role of transportation is very important in a SSCN. But it is also important to see the environmental impacts of transport, because it causes 75% of all carbon monoxide (CO) emissions, 40% of hydrocarbons (HC) and 48% of nitrogen oxide (NO).[185] Especially industrialised countries play a major role in polluting the air. Besides the different forms of emissions transport has many other environmental effects as it can be seen in figure 12.

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181 Lowe [Resource 1998], pp. 43.

182 Breitenbaumer [Recyclingnetzwerke 1998], pp. 304.

183 For further aspects of cooperation and information flow see Kreikebaum [Ecology 1998], pp. 60-65, Kaluza [Verwertungsnetzwerke 2002], pp. 80.

184 Kumar/Malegeant [Supply Chain 2005], pp. 7.

185 Vasconcellos [Transport 1997], pp. 80.

	Source and impact	
Foster (1974)	Bovy (1990)*	Button (1993)
Noise	Air pollution	Air pollution
Vibration	Noise	Water resources
Air pollution	Land resources	Land resources
Dirt	Water resources	Solid waste
Visual intrusion	Solid waste	Noise
Loss of privacy	Accidents	Accident risk
Change in light	Energy resources	Other (disruption, congestion)
Neighbourhood severance	Urban landscape	
Relocation		
Disruption during construction		
Accidents		
Pedestrian journeys		
Congestion		

*Urban road transport only.

Source: Vasconcellos [Transport 1997], pp. 80

Figure 12: Environmental impacts of transport

Since transport is a major polluter legal requirements more and more force economies to use alternative and more sustainable transport methods. The Kyoto protocol regarding greenhouse gas emissions places requirements on the signers which are not easily to fulfil without changing both public and business transportation methods.[186] The pressure on economies results in a direct legal pressure on business organizations like the local regulations of road pricing[187] and the different forms of kilometre charges.[188]

In a SSCN economic forms of ecological sustainable transportation have to be found. Because of the scientific uncertainty[189] and the differences in geographical, infrastructural and market circumstances as well as products and industries there is no generic solution for green transportation. However, there are different methods of a more sustainable transport policy.

186 Good examples for that are the scenarios made in Australia regarding greenhouse gas emissions which can be seen at Dicks et al. [Energy 2004], pp. 7.

187 Chin [Air Pollution 1996], pp. 793.

188 Ubbels et al. [Transport 2002], pp. 258.

189 See a critical approach regarding sustainable transport systems at Black [Transportation 2001], pp. 2.

Methods like switching to more fuel efficient modes of transport restrain the use of cars in environmentally sensitive areas.[190] A switch to alternative fuels for vehicles and proper composition of the vehicle stock in terms of age and engine size[191] can also be applied on a supply chain network level.

Besides regulations there is nowadays also an economic reason to search for sustainable transport systems, namely the stable raising oil prices. As a result JIT philosophy and so transportation has to be retraced.[192]

In order to determine the environmental and economic most sustainable alternative the method of cost-benefit analysis (CBA)[193] has to be extended about environmental issues and has to be carried out on a supply chain level. With this method it is possible to weigh the different aspects of environmental effects. A CBA usually comprises eight steps:

1. Defining the project (in relation to the baseline situation)
2. Identifying all effects
3. Identifying economically/ecologically relevant effects
4. Physically quantifying these effects
5. Monetising the effects
6. Discounting the values
7. Comparing the sum of discounted costs and benefits
8. Doing a sensitivity analysis.[194]

The result of the CBA and the improved planning processes within the SSCN should lead to the selection of the most suitable transportation system in an environmental

190 Although vehicle emission control, which relates to improvements made to vehicle technology in order to decrease average emissions, is a mandatory tool regarding environmental efforts relating to transport is in itself not effective in gaining sustainability, see Vasconcellos [Transport 1997], pp. 86. As an example the energy needed to drive one vehicle for 1 km fell by 2.63% from 1984 to 1993 in the UK, but the total number of passenger-km rose by 27%, a growth outweighing the gain in energy efficiency, see Saleh et al. [Determinants 1998], pp. 93.

191 Heseltine/Nelson [Transport 1996], pp. 78.

192 Heintze [Krise 2005], pp. 34.

193 An case study regarding the method in the case of noise pollution can be found at Nijland et al. [Costs 2003], pp. 133.

194 Nijland et al. [Costs 2003], pp. 133.

and economical sense. This for example could mean the use of railway or intermodal transport instead of trucking.

5.3.4.2 Reverse logistics

From an environmental perspective reverse logistics mainly concentrates on the return of recyclable or reusable products and materials into the forward supply chain and from the business perspective on returned and warranted items that may not even have been used.[195] Proper reverse logistics is not only important because of sustainability reasons but also because of return policy liberalization. The rate of returns reaches 10-15 percent of sales in some retail industries and up to 40 percent in catalogue and internet retailing.[196] According to The Council of Logistics Management reverse logistics is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.[197]

Reverse logistics activities can count a high share of total logistic costs to a company depending on the business and the degree of activities.[198] Within a reverse logistics channel there are different actions: collection, transportation, separation, inspection, densification, re-processing, delivery, disposal, re-distribution and integration.[199] A more strategic approach of reverse logistics differentiates between three main phases of reverse logistics. These are reverse distribution (the collection and transportation of used products and packages), inventory management (controlling external component orders and the internal component recovery process to guarantee a required service level and to minimize fixed and variable costs) and production planning (connected to the specific forms of reuse).[200] Since the phase of production planning is connected to the specific forms of reuse and problems emerging here e.g. by recycling are mainly technical and from a production

195 Sarkis [Management 2003], pp. 399.

196 Horvath et al. [Liquidity 2005], pp. 191, Chouinard et al. [Reverse Logistics 2005], pp. 105.

197 Krumwiede/Sheu [Reverse Logistics 2002], pp. 326.

198 Krumwiede/Sheu [Reverse Logistics 2002], pp. 326.

199 Sarkis [Management 2003], pp. 399, Kumar/Malegeant [Supply Chain 2005], pp. 3, Krumwiede/Sheu [Reverse Logistics 2002], pp. 327.

200 Fleischmann et al. [Reverse Logistics 1997], pp. 4.

management point of view these activities do not differ from other production processes we consider only the first two reverse logistics activities in the following.[201]

Reverse distribution can take place through the original forward channel, through a separate reverse channel, or through combinations of the forward and the reverse channel.[202] Because of the already mentioned territorial aspect of recycling it is important to consider separate channels concerning third party companies outside the SSCN. This is a suitable way to ensure the collection of used products or components outside the regional limited production network.

Collection of used products is very important since it potentially represents a significant part of the total costs of reverse logistic activities.[203] In order to reduce collection costs there are different techniques. Some of the most expensive activities may be shifted onto the customers, e.g. installing some drop-points where customers can hand in used products like in the case of public glass or paper recollection boxes and consumer electronics handed in at retail outlets. These different drop-off locations can be also given on the firm's website). This method reduces transportation, but additional storage space is required and the approach may be limited to relatively small, low-value consumer products. Another method is combining collection with other transportation flows. Especially the combination with distribution is an auspicious approach because synergies can appear. Existing recollection methods and their advantages and disadvantages in the case of Nike's reuse-a-shoe program can bee seen in figure 13.

Collection option	Nike		Donor	
	Benefits	Disadvantages	Benefits	Disadvantages
1. Mail	No transport or storage costs	None	None Convenience	Hassles: packaging
2. Local store	None	Transport or storage costs	No cost Convenience	None
3. Recycle partner	No product acquisition costs	Limited transport costs	No cost	None

Source: Kumar/Malegeant [Supply Chain 2005], pp. 7.

Figure 13: Benefits and disadvantages of the "reuse-a-shoe" program

201 For a detailed discussion see Kaluza [PPS-Systeme 2001] and Kaluza et al. [Konzeption 2001].

202 Fleischmann et al. [Reverse Logistics 1997], pp. 4.

203 Kumar/Malegeant [Supply Chain 2005], pp. 4.

Nike authorized the National Recycling Coalition, which is a non-profit organization, for providing each organization (in this case re-collectors) with communication tools to promote its collection effort, including customizable radio spots, media releases, posters, and print ads and creates a grant for participating recycling organizations which successfully apply the program.[204] This approach can successfully contribute the building up of recollection channels as well as building up a trustful relationship to the customers.

Regarding raw materials and inventory management the producers have two alternatives to fulfil the demands. Ordering the required raw material externally or bringing back old products in good conditions. Overhauling may have both ecological and economic benefits but makes planning more difficult since the producer typically has little control on the quality, quantity and timing of the return flow e.g. because of take-back obligations which results in higher chain fragility.[205] Without recycling relationships fragility is also present because of existing raw material and product relationships but in a SSCN there are also waste relationships which results in uncertainties regarding quality, quantity and timing.

To structure and organize reverse logistics activities within the SSCN, the following challenges have to be solved: analysis of possible markets for recovered products, examination of the requirements for the reverse logistics network, definition of the performance criteria of the network, determination of the degree of integration of reverse logistics within the regular supply chain network (centralized or decentralized network, number of levels of the network, dedicated resources or common resources), definition of operational processes, definition of the required information, and the establishment and continuous improvement of the supply loop. In order to be able to manage the return flows and the processing of recovered products, organizations have to store and process data for any given product, integrate available information into decision-making, and use information for the improvement of products, which can regard design, production, distribution, maintenance, recovery and processing of the recovered products.[206]

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204 Kumar/Malegeant [Supply Chain 2005], pp. 6.

205 Kaluza et al. [Konzeption 2001], pp. 20, Fleischmann et al. [Reverse Logistics 1997], pp. 7.

206 Chouinard et al. [Reverse Logistics 2005], pp. 109.

When introducing a reverse logistics system the complexity of the network increases as a result of the aforementioned additional and uncertain processing and transportation processes. Together with the already existing uncertainty at the various levels of the supply chain as a result of the variability of demand, processing, supply and transportation a high level of complexity is reached.[207] In order to develop sustainable structures in the SSCN the higher degree of complexity has to be managed.[208] On the other side the fragility of the SSCN has to be decreased. This is an important postulation since the alliance of the involved companies should has a long-term configuration.

One possible solution for lower fragility is compensation for the company meeting temporary production or marketing problems because of integrating green aspects by other companies of the SSCN. Theoretically it seems to be a good solution and among given circumstances it can work well.[209] But in general it does not seem to be easily realizable. A probably more feasible solution can be a fond created by the supply chain members, where companies having temporary market problems can get financial help from it. Another possibility is to lower fragility by lowering the dominance of the focal company, which means to have more similar, but smaller key factories within the system. This solution is contradictory from an economic-technical point of view since it contravenes the principle of growing economy of scale which is peculiar in most industries. However, with the advances of automation the economy of large scale standard processes has become less compelling. As a result of the high-speed changing customer demand there is now more technical and economical scope for well controlled diversified smaller scale production,[210] which is also in progress for reverse logistics processes.[211]

In networks of low complexity, the elements and waste exchange relations are more clearly observable and coordination tasks are cheap and simple to carry out.[212] Also, there is an increasing chance that managers of the companies know each other

[207] Srinivasan/Moon [Networks 1999], pp. 616.

[208] Wallner [Industry 1999], pp. 51.

[209] Zhu/Cote [Management 2004], pp. 1032.

[210] Kaluza/Blecker [Wettbewerbsstrategien 2000], pp. 21.

[211] Reijnders [Choice 2000], pp. 129.

[212] Schwarz/Steininger [Network 1997], pp. 54.

personally, which enables problem-solving on an informal basis. However, the smaller the number of companies, the costs of organizing a network are more likely to be borne by a single company, especially when a large portion of waste disposal costs are incurred by this company. The larger the network, the more an individual firm is deterred from bearing costs that primarily benefit other participants. Another problem with enhanced diversity is that it can mean a barrier to the SSCN by resulting in higher transactional costs.[213] There may also be a tension between the participation of diverse actors through increased diversity, the interests of single companies, or differences in management styles and culture.[214] One possible solution for this problem is to establish cooperative relationships with other chains.[215] This would mean a smooth pressure on the participants to keep the conditions of the SSCN since they can be replaced by other companies. But the ability to build trust and agree on basic values within the SSCN should be the present target in order to maintain the symbioses and to sustain the system.

There is a tendency of outsourcing in reverse logistics in conformity with logistics. There are firms like FedEx, ASTRA and GENCO which developed their own systems for reverse logistics management. These not only aid the return process (reverse distribution) but also collect consumer information and track the status of returned items (inventory management) and there are evidences that third-party assistance in reverse logistics can reduce annual logistic costs by 10%.[216] In case of the SSCN a service provider for logistics can also adopt reverse logistics activities in order to the company's concentration on core competencies.

A good mixture of regulatory and non-regulatory drivers can accelerate behavioural changes of actors. Their pollutants, behaviours, and cultures vary widely between and within sectors.[217] This is why a proper development policy has an extremely important role. One tool for encouraging sustainable industrial networks is raising disposal costs, since it is able to enhance efficiency. One indirect effect of raising disposal costs is the contribution to the public opinion because the public budget is

213 Zhu/Cote [Management 2004], pp. 1032.

214 van Kleef/Roome [Management 2005], pp. 8.

215 Zhu/Cote [Management 2004], pp. 1032. For further aspects of complexity see Wallner [Ökologie 1998], pp. 89.

216 Krumwiede/Sheu [Reverse Logistics 2002], pp. 326.

217 Granek/Hassanali [Sustainability 2005], pp. 7.

discharged from subsidies for the waste management. Proper legislation therefore can be supported by the coordinated action of SSCN members by improving their weight in front of the public authority.[218]

6 Economical and ecological benefits in Sustainable Supply Chain Networks through an integrated goal system

Parallel ecological and economic benefits may appear at *sustainable planning.* E.g. packaging has a strong relationship with other elements: packaging characteristics influence distribution, material and energy usage, reverse logistics opportunities and also consumer satisfaction and the buying decision of customers. A typical and simple example for the importance of packaging can be the soft drink or beer industry, where packaging not only influences procurement, production, distribution and reverse logistic opportunities but also consumer behaviour. Another practical example is Siemens which managed to have significant cost savings and in the same time reduced waste and resource use by limiting packaging only to what is necessary for safe transport.[219]

Another good example for the influence of sustainable planning on sustainability is recycling. One barrier for recycling is that the average processing costs exceed the market price in a lot of cases. It results in a goal conflict, according to that recycling as an ecological goal is advantageous but it is not as an economic goal. Eco-design is a tool which can help the dissolution of this contradiction. E.g. designing products for easier disassembly makes the process less labour intensive and avoids the use of such parts which are difficult to recycle.[220]

Although there is no complete dematerialisation in practice a better combination of a product and service that reduces the product elements can lead to environmental and commercial benefits. As an example in the year 2000, Xerox managed to reduce its product material inputs by approximately 140 million pounds with an associated $ 27 million savings.[221] A good example for the possible win-win position with the help

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218 Schwarz/Steininger [Network 1997], pp. 55.

219 Sarkis/Rasheed [Manufacturing 1995], pp. 18.

220 Sarkis/Rasheed [Manufacturing 1995], pp. 20.

221 Maxwell/van der Vorst [Products 2003], pp. 888.

of sustainable planning is SC Johnson.[222] Their environmental representatives also take part in product ideation. It contributes eco-efficiency issues by reformulations of established products, decreasing the company's time to market by flagging potential specification problems before additional resources are invested in development and avoid testing delays and certification problems. Between 1992 and 1996 better environmental performance, in detail the elimination of over 400 million pounds of waste by reductions in the use of raw materials and energy, saved the company a minimum of $120 million. The key of success is eco-design but support functions e.g. ecological purchasing, ecological material management and inventory management are also vital. Using LCA and TCA for designing products results in an economic beneficial solution of environmental problems.[223]

Sustainable planning is a useful tool for identifying and eliminating trade-offs occurring in the product development process.[224] Integrating environmental aspects to product development results in an image improvement, new market opportunities, and often cost reductions even in the short run and contributes the environment and the consumers by improving the function of the product.

Regarding *sustainable purchasing*, purchasing managers often have the perceptions that such programs are not necessarily economical and are expensive to initiate and implement. However, according to empirical studies it indeed can be a significant tool for economic success.[225] Green procurement helps to mitigate the environmental impacts of consumption and is also an effective tool for gaining competitive advantages on international markets.[226] At the present researchers are not sure on how environmental purchasing affects the ability of the firms in other areas. Examples of numerous companies show that it is possible to introduce green requirements into purchasing decisions while the aspects of reducing costs, increasing quality and reducing lead-time through purchasing are not harmed.[227]

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222 Haveman/Dorfman [Green Wall 1999], pp. 11.

223 Hur et al. [Green Productivity 2004], pp. 682.

224 Byggeth/Hochschorner [Ecodesign 2005], pp. 8.

225 Carter et al. [Purchasing 2000], pp. 226.

226 Chen [Purchasing 2005], pp. 929.

227 Handfield et al. [Supplier 2002], pp. 71.

The possible economic advantages of sustainable procurement are also e.g. saving insurance and compensation costs by creating a healthier work environment, certain green products are significantly cheaper, and energy and material savings through the lifecycle exceed higher initial investments.[228] Also, long term cost savings or other benefits directly (e.g. reduced costs over the life of purchased goods) and indirectly (e.g. goodwill among stakeholders or customers) can be reasons for sustainable purchasing.[229] Environmental performance through source reduction strategies including recycling, reuse, and waste elimination strategies that encompass scrapping, sorting for non-toxic incineration, and biodegradable packaging can be improved. On the economic side there are the increasing public demand for environmentally safe products and potential overall reductions in costs which may provide firms with ecological procurement practices a competitive advantage in the marketplace.[230] In theory sustainable purchasing is able to improve a firm's economic performance by e.g. reducing disposal and liability costs, conserving resources and improving the image.[231]

Concerning *recycling* and quality problems, there are examples that the quality of recycled materials is better than of virgin ones (e.g. recycled-content paper in photocopiers) and in many other cases the products made of recycled materials are considered acceptable for many applications.[232] The best known examples for both ecologically and economical successful remanufacturing systems are the ones belonging to Xerox and Siemens. By offering customers the chance of returning the expired equipment Xerox gains e.g. annual savings of $ 200 million.[233] In the case of Xerox the reason for applying such a remanufacturing activity was the cost structure of the company and the need for making better use of the machines which remain company property. The actions taken made sense for both the business and the environment.

228 Mastny [Purchasing 2004], pp. 163.

229 Byggeth/Hochschorner [Ecodesign 2005], pp. 2.

230 Zsidisin/Hendrick [Purchasing 1998], pp. 313.

231 Carter et al. [Purchasing 2000], pp. 220.

232 Sarkis/Rasheed [Manufacturing 1995], pp. 20.

233 Hutchinson [Environment 1996], pp. 18.

The network level has the advantage that it is possible to generate proper information flows through long term relationships. This information channels secure that there are less hidden negative environmental and economic effects of products within the chain and also influence the behaviour of firms into a positive ecologically and economically direction through feedbacks.[234] There are successful examples of having a recycling network with both economic and ecological benefits in the same time. Kalundborg is the most popular example for that.[235] This network has an estimated economical benefit of $ 12 – 15 million a year.[236] Besides the economical advantages there are many environmental benefits.[237] Combined heat and power schemes have enabled households to discontinue the use of 3500 individual oil burning domestic heating systems, 330.000 tons of treated sludge from the fish farm are annually used as fertiliser on nearby fields, desulphurization at the power station removes 95% of the sulphur dioxide, which is washed with lime-water to produce 250 tons of gypsum every 24 hours which is also used. Furthermore 3.000 tons of pure sulphur each year are used by a manufacturer of sulphuric acid, the oil refinery's cleaned flue gas is sold to the power plant, which has been adapted to burn coal or gas which has reduced the power plant's coal consumption by 30.000 tons annually.

There are some other networks, which provide economical and ecological benefits. One example for an ecologically and economical successful business practice is the Guitang Group in China.[238] There are two main supply chains within the group: alcohol and paper. Each down-stream plant uses ‘wastes’ from its up-stream plant as raw materials along the chain. E.g. the alcohol plant utilises the used molasses from the sugar refinery as raw material and the alcohol residue from alcohol plant is used by the fertilizer plant to make fertilizers. With these and some other activities the group does not only reduce waste but also improves its financial performance. The recycling network in the Austrian province Styria similar to Kalundborg also includes recycling structures that have as focal enterprises typical waste recipients, e.g.

234 Schwarz/Steininger [Network 1997], pp. 53.

235 Christensen [Kalundborg 1998], pp. 324.

236 Heeres et al. [Eco 2004], pp. 986.

237 Hutchinson [Environment 1996], pp. 20.

238 Zhu/Cote [Management 2004], pp. 1032.

cement factories and steel producers, and provides a wide range of both economical and ecological benefits.[239]

Companies applying *reverse logistics* (e.g. Xerox, Home Depot, Mobil and Eastman Kodak) have recognised that it can result in cost reductions in inventory carrying costs, transportation and waste disposal and have also seen the positive effect of reverse logistics on image.[240] It is also more and more common that firms rather lease than sell products to costumers. This method has the advantage that companies can recover these products for recycling or remanufacturing and gives an opportunity for greater costumer retention and lower manufacturing costs. Companies in e.g. the photocopiers area managed to gain significant profits and business value through reverse logistics. This does not mean that building out reverse logistic systems automatically results in better economic and environmental performance. Gaining these advantages means challenges and requires consideration of life-cycle impacts (including e.g. the environmental aspects of used components).[241]

Reverse logistics is also able to increase consumer satisfaction (and also sales and profitability) through enabling liberalized product return policies. This is possible because of the created return channels which enable reverse logistics in order to cost efficiency. Reverse logistics – if handled correctly – provides an excellent opportunity to turn lost sales into additional revenues by permitting to pay attention at the return risk.[242] Therefore an adequate integration of reverse logistics activities results in a double effect within the SSCN in an economic and environmental context. First, the efforts on product returns and their processing results in competitive strategies which contribute to a better performance of current activities of the supply chain, since the focus until now was primarily on the distribution of new products. Secondly, the new supply chain structure also integrating reverse logistics orients itself to ensure a robust management of any additional activities.[243] Figure 14 shows

239 Schwarz/Steininger [Network 1997], pp. 50.

240 Krumwiede/Sheu [Reverse Logistics 2002], pp. 326.

241 Lippmann [Management 1999], pp. 180.

242 Horvath et al. [Liquidity 2005], pp. 192.

243 Chouinard et al. [Reverse Logistics 2005], pp. 106.

further possible benefits when building up a closed-loop supply chain in order to realize a circular economy.

Service/market	Value creation opportunities	Environment/safety
Return service improves customer satisfaction Reduced R&D time – time to market Increased spare parts availability Timely retrofit through early take-back Improved product quality through re-engineering Pro-active repairs Green image	Reduced liability risk Regain value of materials and components Regain value of labour Avoid disposal costs Reduced obsolescence risk through timely return Less new production of spare parts Returns reduction	Reduced environmental impact Compliance with legislation More reliable recalls of defect products

Source: Kumar/Malegeant [Supply Chain 2005], pp. 4

Figure 14: Closed-loop supply chain benefits and value creation opportunities

Other empirical investigations also suggest both environmental and economic performance improvement when integrating sustainability in supply chains. The Irish Environmentally Superior Products (ESP) initiative involving 12 companies between 1999 and 2001 found that focusing on the supply chain results in eco-efficiencies.[244] Reduced volume of raw materials, eliminated and/or reduced hazardous raw materials usage, reduced energy usage and eliminated/reduced waste generation are only some contributions towards sustainability. Business benefits like improved product/service functionality, cost savings, competitive advantage, higher sales, new business opportunities, capability building in terms of knowledge and expertise, improved supplier relationships and corporate reputation were also realised. There are some realized examples for developed products like electronic circuit boards with a reduced materials content and increased energy efficiency, computers with an extended life as well as increased reuse/recycling options at end of life, recyclable or reusable toner cartridges, office chairs designed to be disassembled and upgraded to extend operational life as well as maximising reuse/recycling options at eventual end

[244] Maxwell/van der Vorst [Products 2003], pp. 890.

of life, reusable or returnable packaging for the microelectronics sector and outdoor recycled plastic furniture manufactured from reclaimed healthcare waste plastics.[245]

7 Conclusion

In our contribution, we highlighted the importance of integrating ecological goals into business and discussed the problems appearing by this integration. Mainly there are goal conflicts and barriers when integrating ecological and economical goals simultaneously. Therefore we claimed the possibility to construct a SSCN in order to solve this goal conflicts. With a SSCN, it is possible to turn from a flow economy to a circular economy by integrating ecological and economic issues. This benefits ecological and economic development towards sustainability within the SSCN, which leads to the improvement of the competitive position for all participants.

We have shown that four principles are essential to reach a sustainable configuration of the SSCN. These are the setting up of sustainable goals and strategies, formulating and introducing sustainable win-win relationships, implementing intelligent systems and resources, as well as arranging cooperative R&D with a focus on sustainability. These strategic principals shape the SSCN, its specific configuration, and the relationships between the participating enterprises. As we have demonstrated, the members of the SSCN are not only companies of the origin supply chain. Remanufacturing/Re-use, Recycling, and Disposal/Incineration enterprises, but also logistics and service providers are important partners in a SSCN.

Afterwards we have discussed different elements for an effective dissolution of economical and ecological goal conflicts. We have illustrated sustainable planning, sustainable purchasing, sustainable production (forward and reverse production processes), and sustainable distribution (transportation and reverse logistics) as potential sources for the management of goal conflicts. As it could be seen there are a lot of interdependencies between these components. Therefore the adjustment of these interdependencies is an important activity in order to solve the emerging goal conflicts.

Finally we visualized that the building up of a SSCN contributes both the economical and the ecological development of the participating companies. Therefore the whole

[245] Maxwell/van der Vorst [Products 2003], pp. 891.

supply chain network can reach a higher degree of sustainability, which means that there are significant improvements in an economical, ecological and social context.

Future research in this area has to focus on the practical implementation of the concept of SSCN. Measurement-systems must be developed and verified for steering the SSCN effectively and efficiently. Within empirical projects, the validity of the stated arguments has to be tested.

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