

Environmental Impact of Supply Chains

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1. Introduction

Focus on sustainable development and green economics has been growing in the past two decades in a myriad of different fields. As such, there has been a great deal of research performed in the fields connected with supply chains and logistics. Different buzzwords have been used such as green supply chain management, green logistics, sustainable supply chains, sustainable transport etc.

The first part of the chapter summarizes the meaning of terms “green” and “sustainable” while outlining their importance in relation to supply chain management. The relation is emphasized with end consumer product examples from the viewpoints of green and sustainable.

The second part of the chapter provides a literature review of recently published scientific papers of the fields relating to green and sustainable supply chain management. The review includes scientific papers from various research fields such as supply chain management, operations research, sustainable development, green environment, logistics etc. Several other reviews that were conducted in past decade are also referenced in order to provide additional insight into the field. Special focus of the literature review lies on interdisciplinary papers that cover different interconnected fields of research with focus on sustainable development, green environment and supply chains.

Third part of the chapter presents main drivers and barriers for companies and supply chains when adopting green and sustainable supply chain management concepts.

Based on literature review the outlines for further research are presented in the last part of the chapter.

2. Green and sustainable. Which is what?

Focus on sustainability and green has been growing in the past two decades in a myriad of different fields. As such, there has been a great deal of research performed in the fields connected with supply chains and logistics. The words green and sustainable have been popularized and used in connection to various other terms. As a result different buzzwords have been coined such as green supply chains, green logistics, sustainable supply chains, sustainable transport etc.

Even though the terms green and sustainable development have been widely popularized there are often misconceptions or misunderstandings as to what they mean. Therefore this section of the chapter will briefly describe both terms and provide several examples which will provide clear and concise differentiation between the two.

Sustainable development has become widely used and promoted by various government and non-government organizations since the eighties (Bebbington & Gray, 2001). The most known and widely used definition for sustainable development is the one from the United Nations World Commission on Environment and Development which defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Our Common Future (The Brundtland Report), 1987).

However, lack of consistency of interpretation of sustainable development phrase has been identified (Lélé, 1991). Therefore, many different interpretations of sustainable development are possible, with some of them presented in Hopwood, Mellor and O’Brien (2005). The authors also propose a classification and mapping methodology of different trends of thought on sustainable development, their political and policy frameworks and their attitudes towards change and means of change, all of which is an extension of previous research of this field.

Since the goal of this chapter is to provide insight into differences between green and sustainable development a general definition of sustainable development based on the research presented above is defined. Sustainable development stands for ways of environmental exploitation that will enable the same or comparable exploitation for further generations. Therefore something that is sustainable lowers the pressure on environment to such levels that the environment can renew the exploited sources which will be used by future generations.

The other term which we deal with is “green” as in relation to green economy. The term is often used in relation to sustainable development; however they do not necessarily mean the same thing. Pearce (1992) argues that achieving environmental improvement will require policies that use selfishness rather than opposing it. Another often used expression is also green economics. An extensive history on development of green economics can be found in Wall (2006) where the author also discusses green economics in relation to global economy.

The latest definition of green economy is based on United Nations Environment Programme (United Nations Environment Programme, 2010) which implies that green economy results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.

Based on definitions presented above it is therefore possible to discern the difference between sustainable and green, even though both expressions are often used interchangeably. Therefore we briefly outline a consumer product point of view and associate it with green and sustainable development. A consumer product can be green which means that it lowers the impact on environment by its use while it is not necessarily sustainable as in produced in a way which ensures minimum impact on the environment in forms of resource exploitation and pollution.

Below are a few examples of consumer products where we try to discern if they are green and sustainable:

- **Bicycle.** A bicycle enables lower pollution when used for travel in urban areas. If compared to alternatives such as a car, a motorcycle or even public transport which consume fuel and pollute the air or consume electricity, it presents a much “greener” alternative. However, an important question that needs to be asked is whether the bicycle is also a product that helps to add to sustainable development. The answer depends on the way the bicycle was designed, manufactured, shipped and sold. If the manufacturer uses out of date production processes, shipper uses high polluting vehicles and the store discards defective bikes instead of properly dismantling them, then there is a high chance that this particular bicycle will not add to sustainable development, since the impact on environment from manufacturer to the end customer would be too high to offset the benefits of the “green” use of the bike when compared to other mentioned transportation options. It is important to note the role of supply chain in the above example.
- **Sports car.** This is a product that enables travel, however the fuel consumption is a lot higher than a lot of other means of travel. Therefore it cannot be labeled as a green product. However, a sports car can be manufactured in an advanced manufacturing plant, using state-of-the-art technologies which have a very low impact on the environment. Additionally, materials used in vehicle production can come from recycled products while the vehicle itself can be recycled after the end of its use. Therefore a sports car can be a sustainable product while not being a green product.

Both of the above products can be both green and sustainable and the presented examples are just extreme examples. Below is another example of a product that is both green and sustainable:

- **Digital reader.** Digital reader enables the consumer to read various published content without use of paper. Since a digital reader consumes very low amount of power compared to alternatives (such as other types of displays) it can be considered green. If the production and distribution of the reader also leaves minimum impact on the environment it is also a sustainable product.

As we can see from the examples above supply chains have a significant impact on whether a product is considered sustainable, green or both.

Therefore we present a recent literature review on green and sustainable supply chains and supply chain management in the next section of this chapter. The last section of the chapter presents a conclusion and outlines possibilities for further research in this field which are based on the literature review.

3. Green and sustainable supply chains

As seen in previous section of this chapter the importance of green and sustainable supply chains is increasing as the companies start to compete on a supply chain level instead on a level of a particular company. Therefore the need for the research of sustainable development and green environment is also rising, in particular in connection to supply chain management. Therefore this section of the chapter provides an outline about past and

current research conducted in these fields. The conclusions and further research pointers are presented in the last section of the chapter.

There are several different definitions of green supply chain management and sustainable supply chain management. Some of the most recent ones based on extensive literature reviews are presented in the following paragraphs.

Srivastava (2007) identifies green supply chain management as “integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life.”

Sarkis, Zhu and Lai (2011) define green supply chain management as “integrating environmental concerns into the inter-organizational practices of supply chain management including reverse logistics”.

Carter and Rogers (2008) define sustainable supply chain management as “strategic, transparent integration and achievement of an organization’s social, environmental, and economic goals in the systemic coordination of key inter organizational business processes for improving the long-term economic performance of the individual company and its supply chains” which is based on intersection of social, environmental and economic performance and the supporting facets of this triple bottom line which are risk management, transparency, strategy and organizational culture.

Seuring and Müller (2008) define sustainable supply chain management as “the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements”.

The above definitions provide an important insight in what a green and sustainable supply chain is. Green supply chain management definitions place the emphasis on integration of environmental issues into supply chain management. On the other hand the sustainable supply chain management definitions employ three different dimensions to sustainable supply chains, which are economic, environmental and social.

While green supply chain management research places the emphasis on one of the three dimensions, the sustainable supply chain management research tries to address all three. As we will see in the following chapter the most often researched dimension is economic, followed by environmental dimension, while social dimension has not often been included in the research.

Promotion and development of reverse logistics and closed loop supply chains in the past decade has paved the road for green supply chain management (Hoek, 1999). It is not enough for supply chains to merely introduce a reverse flow of goods, but they also need to be properly re-manufactured, disassembled or disposed of (Hoek, 1999). While reverse logistics can be seen as a part of sustainable development they differ from green logistics as that considers environmental aspects to all logistics activities and has been focused specifically on forward logistics (De Brito & Dekker, 2003).

The research interest in everything that is green and sustainable in connection with supply chains, logistics and transport has increased dramatically in the last decade.

Table 1 shows data obtained on ISI Web of Science and relates to the number of publications per year when searching for different keywords.

Year	Number of hits
2011	58
2010	86
2009	45
2008	48
2007	42
2006	20
2005	20
2004	17
2003	16
2002	11
2001	8
2000	13
1999	10
1998	8
1997	8
1996	6
1995	3
before 1995	3

Table 1. Search results for different keywords on Web of Science

The keywords that were used for searches presented in Table 1 were green supply chain, green logistics, sustainable supply chain, sustainable logistics, green transport and sustainable transport. The number of hits for each year presents the cumulative of hits for all search results. The highest search results were for the keywords sustainable transport, which constitute for about one third of overall searches, followed by green supply chain and sustainable supply chain keywords.

Due to the time of this publication the search results for year 2011 are only available for first half of the year. If the result was to be extrapolated to the entire year 2011 the number of hits would be well over 100.

The amount of hits before year 1995 is cumulative, indicating that there was not much research interest in this field before that date. One of the reasons for lack of hits before year 1995 is also the late development of the term supply chain management which was first introduced in the eighties (Ganeshan, Jack, Magazine, & Stephens, 1998).

As we can see from the above fast growth in research interest has led to a fast rise of publications on the green and sustainable supply chain topics, therefore the need for literature classification has arose with different literature reviews on topics of green supply chain management and sustainable supply chain management being conducted.

Below we present several literature review papers that have been published in the last few years that deal with literature review of either green or sustainable supply chain management and propose further research which is summarized in the last section of this chapter.

A throughout research on the topic with proposed framework for sustainable supply chain management that includes papers from 1994 to 2007 has been conducted by Seuring and Müller (2008). Authors assume that economic dimension has been covered by all papers included in research since the papers were from management journals and publications, therefore only environmental and social issues were an issue. Papers which included all three dimensions were classified as sustainable. Out of 191 papers only 31 were classified as addressing sustainability related issues. The proposed framework consists of three parts: triggers for sustainable supply chain management, supplier management for risks and performance, and supply chain management for sustainable products. Drivers and barriers of the proposed framework are presented under section 4 of this chapter.

Another literature review has been conducted by (Srivastava, 2007) which includes around 1500 published units in forms of books and papers dating back to 1990. The research classifies green supply chain management based on the problem context in supply chain's major influential areas, which are literature highlighting the importance of green supply chain management, literature on green design and literature on green operations, while ignoring literature on green logistics as is operational and not strategic in nature. Another proposed classification of green supply chain management literature in the research is by methodology and approach usage: thought papers and perspectives, frameworks and approaches, empirical studies, mathematical modeling approaches, reviews. The authors' findings show that emphasis in green supply chain management research was on quality, operations strategy, supply chain management, product and process technologies. However, they suggest that more integrative contributions are needed such as intra- and inter- firm diffusion of best practices, green technology transfer and environmental performance measurement.

Categorization of green supply chain research under nine broad organizational theories has also been conducted (Sarkis et al., 2011), focusing on the theories that were used more often in the published papers, which include complexity theory, ecological modernization theory, information theory, institutional theory, resource based view, resource dependence theory, social network theory, stakeholder theory and transaction cost economics. Authors argue that organizational theory provides a very valuable source of theoretical underpinnings for investigating and furthering research in green supply chain management and that this type of research has future potential. Furthermore, authors also identify organizational theories that would help to further understand green supply chain management which are diffusion of innovation, path dependency, social embeddedness and structuration theories.

Carter and Rogers (2008) perform a large-scale literature review and use conceptual theory building to introduce the concept of sustainability to the field of supply chain management.

They propose a sustainable supply chain management framework based on resource dependence theory, transaction cost economics, population ecology and resource based view of the company. They suggest that sustainability is an intersection of environmental, social and economic performance.

Further research (Carter & Easton, 2011) has shown that environmental aspects of supply chain management have been the leading focus. The share of research employing any sort of theory has been increasing, with stakeholder theory being the most prevalent. Furthermore, the research shows that the sustainable supply chain management research focus in past twenty years has focused on consumer related and transport industries; however the majority of studies focus on multiple industries. Majority of sustainable supply chain management research uses survey as the primary data collection methodology but the number of papers using this methodology is declining. On the other hand research using case studies, archival data and individual interviews are on the rise.

Other authors agree that in the past most of the research has been focused on environmental aspects of manufacturing while largely ignoring other aspects of sustainability or the challenges for the service sector (Piplani, Pujawan, & Ray, 2008).

Another recent literature review concerning green supply chain management has been published by Carvalho and Machado (2009). The paper amongst other things identifies supply chain characteristics that must be managed to assure supply chain's harmonization with the ecologic and environmental aspects that production processes may attend.

4. Drivers and barriers of green and sustainable supply chain management

One of the most important questions is why green and sustainable supply chain management would even be considered. Companies strive to achieve maximum profitability which does not always include sustainable development or green products. Therefore companies and supply chains need incentives in order to pursue green and sustainable supply chain management. These incentives can be found from different sources, usually internal and external.

A recent literature review and an explorative study (Walker, Di Sisto, & McBain, 2008) has identified several different drivers that promote green supply chain management. On one side there are internal drivers in form of different organizational factors, while on the other side there are external drivers such as regulation, customers, competitors, society and suppliers. Organizations that were included in the research tend to be more incited by external drivers than internal drivers.

Seuring and Müller (2008) determine that external pressures and incentives that are most common are legal demands, customer demands and response to stakeholders, while reputation loss is one of the least common incentives. On the other hand internal barriers for sustainable supply chain management were higher costs, coordination complexity, coordination effort and insufficient or missing communication in the supply chain, while important internal supporting factors are company-overlapping communication, management system, monitoring, evaluation, reporting, sanctions.

Another recent study (Mann, Kumar, Kumar, & Mann, 2010) identified drivers that promote sustainable supply chain management which are also separated in two groups: internal and external. Internal drivers are financial, internal business process and drivers related to customers. External drivers according to this study are legislation and environmental drivers.

Empirical study of sustainable supply management (Ageron, Gunasekaran, & Spalanzani, 2011) ranks different factors in accordance to their importance according to the study. Most important motivator for companies to employ sustainable supply chain management is customer satisfaction, followed by supplier's ability to innovate. The least important are supplier lead-time and order fulfillment costs. Authors conclude that external factors are more important than internal.

Next to drivers some authors also identify pressures and form a joint group of drivers and pressures (Zhu & Sarkis, 2006). Those drivers and pressures are: regulations, marketing, suppliers, competitors and internal factors. The drivers are not universal across different industries which means that companies or supply chains are influenced by the industry that they operate in (Zhu & Sarkis, 2006).

Distinction must also be made when comparing different sizes of companies that are included in supply chains. The drivers for green supply chain management initiatives for small and medium suppliers can be different from drivers of large companies and consist of buyer influence, government involvement and company's internal green supply chain readiness (Lee, 2008).

However, there are also barriers when considering green supply chain management. Walker et al. (2008) identify two types of barriers. Internal barriers are costs and lack of legitimacy while external barriers are regulation, poor supplier commitment and industry specific barriers. Ageron et al. (2011) provide a research study which financial factors as ones that present the greatest barrier, namely the difficulty in assessing the amount to invest and evaluating the return on investment.

5. Conclusion and outlines for further research

In the first part of the chapter we provided general definitions for sustainable development and green economy. We have emphasized the importance of both concepts in relation to supply chain management. Hence we delved deeper into this connection in the second part of the chapter where we provided the definitions for both green and sustainable supply chain management and outlined the differences between the two. Green supply chain management only addresses environmental dimension of supply chains while sustainable supply chain management also addresses economic and social dimensions of supply chains. Due to identified increased research interest in both topics we exposed several of the recent studies about research on green and sustainable supply chain management. A separate section is also devoted to the drivers and barriers that companies face when introducing green and sustainable supply chain management.

Green and sustainable supply chain management has become an important research topic in the past decade and its popularity is still increasing. Therefore there are a lot of new research questions and issues that are being identified throughout research and practice. We

conclude that environmental impact of supply chains can be enormous due to the presented green and sustainable supply chain management concepts in this chapter. Furthermore, many additional interdisciplinary research questions are being identified by several different researchers and practitioners.

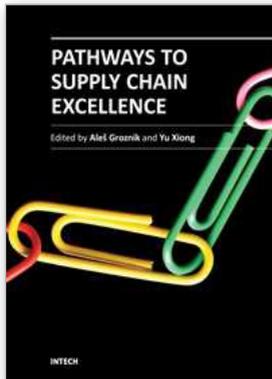
Some of the research challenges in the fields of green and sustainable supply chain management that were outlined by different authors in the past few years are listed and briefly described:

- Promoting the usage of different organizational theories in green and sustainable supply chain management research (Sarkis et al., 2011), with emphasis on transaction cost economics organizational theory (Carter & Easton, 2011).
- Focus on research of individual industries in order to identify types of sustainability activities that are specific to those industries (Carter & Easton, 2011).
- Expanding sustainable development from environmental improvements to social improvements (Seuring & Müller, 2008).
- Changing the unit of analysis from a company to an individual manager in order to find out what drives managers into sustainability commitment (Carter & Easton, 2011) and in relation to that finding out how environmental concern on the minds of the management of firms is independent from that arising from legislation, customer pressure or social activism (Mann et al., 2010).
- Sustainable supply chain management research needs more emphasis on collecting empirical data from companies (Ageron et al., 2011), while also keeping importance of assessing validity instead of only reliability of data used in sustainable and green supply chain management research (Carter & Easton, 2011).
- Focusing more on a theoretical background for green or sustainable supply chain research (Seuring & Müller, 2008).
- Focus on service supply chains instead of just manufacturing supply chains (Carter & Easton, 2011).
- Cross-country empirical studies need to be conducted in order to see if there is any difference in the emerging models for sustainable supply chain management (Ageron et al., 2011).
- Exploring the consequence of green supply chain initiatives in terms of economic and environmental performance of both buyers and suppliers (Lee, 2008).

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Pathways to Supply Chain Excellence

Edited by Dr. Ales Groznik

ISBN 978-953-51-0367-7

Hard cover, 208 pages

Publisher InTech

Published online 16, March, 2012

Published in print edition March, 2012

Over the last decade, supply chain management has advanced from the warehouse and logistics to strategic management. Integrating theory and practices of supply chain management, this book incorporates hands-on literature on selected topics of Value Creation, Supply Chain Management Optimization and Mass-Customization. These topics represent key building blocks in management decisions and highlight the increasing importance of the supply chains supporting the global economy. The coverage focuses on how to build a competitive supply chain using viable management strategies, operational models, and information technology. It includes a core presentation on supply chain management, collaborative planning, advanced planning and budgeting system, risk management and new initiatives such as incorporating anthropometry into design of products.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Aleš Groznik and Jure Erjavec (2012). Environmental Impact of Supply Chains, Pathways to Supply Chain Excellence, Dr. Ales Groznik (Ed.), ISBN: 978-953-51-0367-7, InTech, Available from:

<http://www.intechopen.com/books/pathways-to-supply-chain-excellence/environmental-impact-of-supply-chains>

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