Chapter

Introductory Chapter: Disciplinarity Aspects in Green Supply Chain Design and Operation

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1. Introduction

Supply chain solutions include a wide range of design tasks, especially from logistics point of view. Supply chains perform the integration of procurement, production, service, distribution, and reverse processes. The performance of this integration phenomena of supply chains influences the performance of the value chain and has a great impact on the sustainability, reliability, availability, and cost efficiency. From this point of view, it is important to optimize supply chain solutions and take green aspects into consideration.

The design of supply chain processes includes a wide range of optimization aspects: routing, scheduling, inventory management, layout planning, queueing optimization or assignment. These design tasks are related to the main sub-processes of supply chains: sourcing and extraction of raw materials, processing materials into components, assembling components into the final product, distribution of the final products to the end users, reverse processes of end-of-life products. Green supply chain solutions pose new challenges for researchers and practitioners, as in addition to efficiency, reliability and availability, sustainability can be reclassified as a priority.

This introductory chapter emphasizes the importance of disciplinarities in the design and operation of green supply chain solutions, especially form sustainability point of view.

This introductory paper is organized as follows. Section 2 presents the main aspects of green supply chain solutions. Section 3 summarises the available types of disciplinarities, focusing on interdisciplinarity, multidisciplinarity, crossdisciplinarity, transdisciplinarity, and interdisciplinarity. Section 4 describes the main disciplines regarding green supply chain design and operation research. Conclusions and future research directions are discussed in Section 5.

2. Green and closed supply chain

Green supply chain means the integration of sustainable environmental processes and eco-friendly aspects into conventional supply chain solutions and transform them into green supply chains. It is important to distinguish between green supply chain and sustainable supply chain. Within the frame of sustainable supply chain solutions, the economic aspects have priority, while social and environmental

aspects represent constraints and influences its solutions. In the case of green supply chains the environmental aspects play the most important role, while social and economic aspects have great impact on the environmental aspects (see **Figure 1**).

The definition and scope of green supply chain management has ranged from local green solutions in purchasing, productions and distributions to integrated green supply chains approaches from suppliers to end users, but in our opinion the definition by Srivastava highlighted well the integration aspects, defining the green supply chain management as the "integrating environmental thinking into supply-chain management" and in his definition not only purchasing, production, and distribution but also product design and end-of-life processes represent important aspects of the whole green supply chain [1].

The green supply chain management is defined as an integration of green procurement, green manufacturing, green materials management, green distribution and green reverse processes. This definition is linked to the supply chain management definition from the same authors, where supply chain management is defined as "the coordination and management of a complex network of activities involved in delivering a finished product to the end-user or customer" [2]. As **Figure 2** shows, the procurement or purchasing process includes the sourcing and processing of raw materials for the component manufacturers.

The green production integrates the manufacturing of components and parts and the assembly of the final products from these parts and components. The green distributions is responsible for the environmentally sustainable distribution and marketing processes regarding customers and end users.

While the classic supply chain can be defined as a network of organizations involved, by linking with suppliers and customers in various processes and activities that create value in the form of products and services delivered to end consumers [3]. It is in the case of a green supply chain (as the name suggests) that it should be environmentally friendly. The logistic processes carried out should not cause damage to the natural environment, lead to the lowest possible consumption of water and energy, and not contribute to an increase in the amount of waste in the world.

The concept of a green supply chain and its impact on the environment is widely described in the literature [4–6]. The name (GSC - green supply chain) was first proposed in 1996 by the Manufacturing Research Consortium (MRC) in the USA to comprehensively capture the relationship between the natural environment and production optimization. The green supply chain model is characterized by low emissions, and environmental protection is part of the entire process, from material acquisition to final product delivery and waste management. The extended approach to supply chain management does not end with the delivery of the product to the consumer. They also cover issues related to how the product is used and the end-of-life management processes. The most important classification criteria and how they are understood in a green and traditional supply chain are shown in **Table 1**.

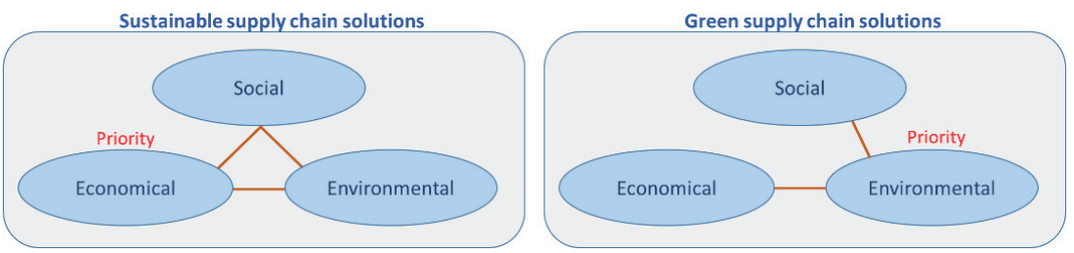

Figure 1.
Sustainable supply chain versus green supply chain.

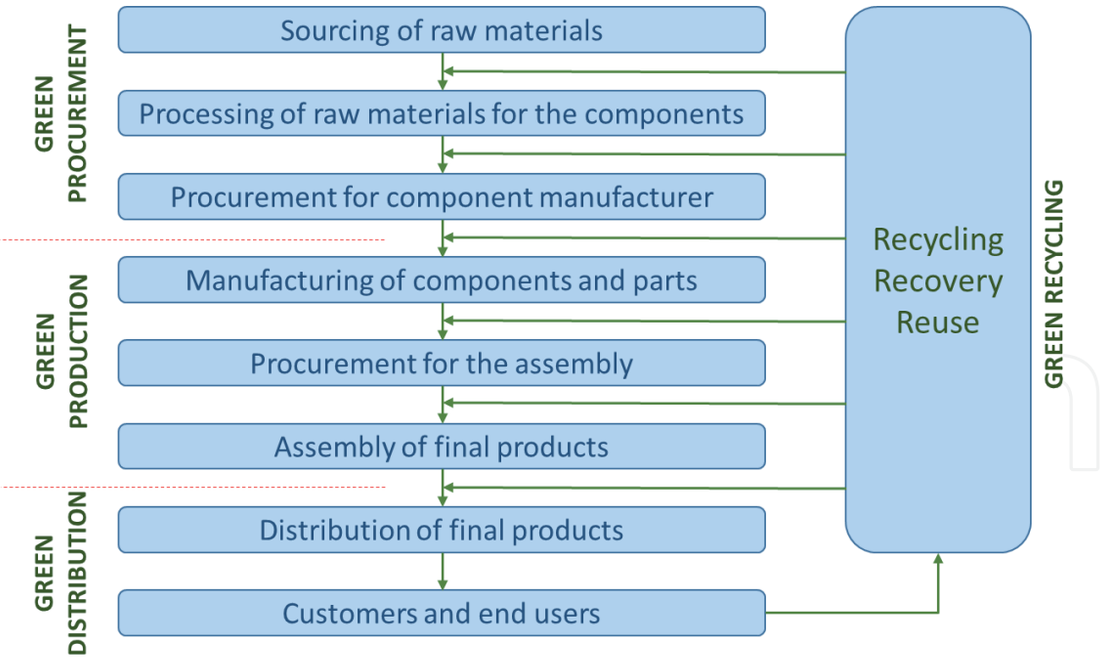

Figure 2.
Simplified process of green supply chain.

Criterion	Classic supply chain	Green (closed) supply chain
Realization of the goal	Cost reduction, improvement of customer service quality and maximization of the company's operating profits.	Saving energy and natural resources. Optimization of economic benefits in the long term.
Process implementation	Irreversible processes in one direction only, from producer to consumer.	Reverse logistics, reversible processes, closed chain circulation, recycling, utilization, reuse.
Environmental Aspects	No environmental impact analysis.	Environmental impact in every process and at every stage of chain development.
Business Aspects	Basic model based on the theory of production and consumption of goods, profit maximization.	Extended to include environmental and corporate social responsibility aspects.

Table 1.
Similarities and differences in different supply chains.

Closed supply chains. The philosophy of recycling of used products is an extension of the GSC concept. The Closed-Loop Supply Chain Management (CLSCM) concept arose from the perceived value in resources that have been treated as waste that needs to be disposed of. The approaches of the GSC and the CLSCM are not mutually exclusive, on the contrary, they should complement each other or constitute a single systemic solution for the design - production - consumption and disposal of goods.

The development of a sustainable approach to supply chain management resulted in a number of solutions that drew attention to the natural environment, and undoubtedly waste had a negative impact on it. herefore, a solution had to be found to reduce their level. It should be remembered that disposal is an expensive process, so in the traditional approach, waste was not a revenue-maximizing factor, but a process cost-increasing factor [7]. Paying attention to their ecological and economic potential has led to the development of reverse logistics, i.e. the concept

of a closed supply chain. The flow of materials from the customer to the manufacturer is becoming more and more important. Managers consider recovering value or disposing of the product. Recovered raw materials are a good source of supply for the material flow that flows to the production department. This allows the supply chain to be closed [8].

Both the GSC and CLSCM approach to supply chain management contain common, environmentally friendly elements, therefore in the literature they are often used interchangeably. What the two approaches have in common is optimized transport, ecology, return logistics, reusable packaging and a sustainable approach to process optimization.

3. Disciplinarities

The function and characteristics of disciplinarities have a great impact on the performance of research processes and on their results. Green supply chains represent complex systems, this complexity has been increased in the last decade caused by the potentials of Industry 4.0 era. The design and operation of these supply chain solutions can include a wide range of knowledge, therefore it is important to take into consideration the connections and impacts of these knowledge and sciences. The connection of the sciences and scientific fields can be described by the aid of the different types of disciplinarities. Researchers stated, that the structure of disciplinarities and their relationship influences the performance of research processes, therefore it is import to analyse the impact of the different disciplinarities on the research [9, 10] and it is forward-looking to find new revolutionary disciplinarities.

One of the most interesting new disciplinarity concept, the alterplinarity was developed for the future art and design research [11], which is based on the fragmentation of distinct disciplines. Within the frame of this part of the chapter, the main directions of disciplinarities are summarized.

Jensenius defined five types of disciplinarities [12]. Intradisciplinarity means the research of a topic within a single discipline and viewing one problem from the perspective of one disciplinary. Multidisciplinarity means, that researchers from different disciplines are working together and they are drawing on their special disciplinary knowledge to solve the problem. Crossdisciplinarity is a special approach of a problem, where the research topic of a disciplinary is viewed from the perspective of another one. Interdisciplinarity represents the integration of knowledge, tools, and methods of different disciplinarities, and lead to the synthesis of diverse approaches. Transdisciplinarity is another form of the integration of different disciplinarities, which lead to the unity of various diverse approaches (see **Figure 3**).

These different types of disciplinarities are used in a wide range of research topics, as the following examples are shown. Within the frame of Antarctic research

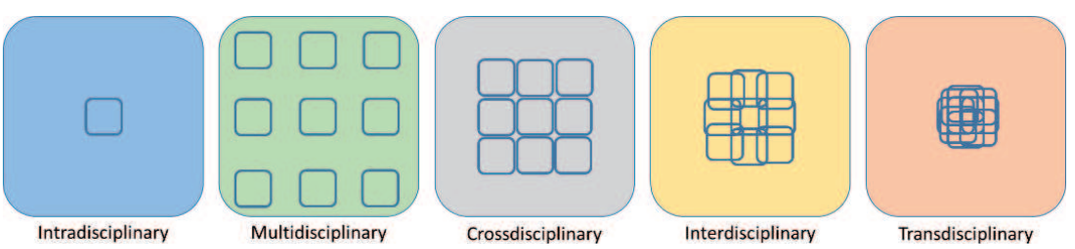

Figure 3.
Different types of disciplinarities by Jensenius [12].

programmes both multidisciplinary and crossdisciplinary approaches was used to link monitoring, biomolecular findings, simulated physical environments, and ecological modelling [13]. Renn describes the importance of transdisciplinary approach, shows the merits, problems and shortcomings of these approaches of research problems and introduces a new curiosity-driven, goal-oriented and catalytic transdisciplinary research concept [14]. In the literature we can find research articles, which are focusing on the importance of the different approaches of disciplinarities [15]. Another aspects of integrations of disciplinarities are shown by Bixler et al. [16] focusing on the use of social network analysis to evaluate scientific integration and transdisciplinarity in research networks. The importance of discplinarities are represented by Balsiger [17]. His research shows, that transdisciplinarity is important not only in the research but in the early phase of education. The different research approaches using intra-, multi-, cross, trans- or interdisciplinarity are used in a wide range of research topics: weather forecast and disaster risk reduction [18], fault diagnosis in engineering [19], medicine [20], logistics [21, 22], supply chain management and transportation [23, 24], robotisation and mechatronics [25, 26], earth sciences [27], and information sciences [28].

4. Disciplinarity aspects in green supply chain design and operation

Within the frame of the design and operation of green supply chain management a wide range of knowledge can be used from different aspects of disciplinarities (see **Figure 4**). This knowledge can be used in different combination to design an improve green supply chain solutions.

The most important aspects of these set of knowledge can be summarized as follows:

- Materials handling: modular and robotised material handling solutions represent the green directions of materials handling in green supply chain solutions. The reusability of pallets, containers and packaging materials in material handling solutions of green supply chain represents an interesting aspect, where the reusability focuses on both economic and environmental dimensions. The greening of material handling operations (loading, unloading, in-plant transportation, sorting) is important not only in production plants, but also it is important to green materials handling in warehouses, logistics centres, and third party logistics providers.

- Transportation is one of the most critical part of the supply chain from environmentally point of view. E-mobility offers sustainable solutions for transportation, including first-mile and last-mile processes (e.g. waste collection, home delivery), but energy generation sources can influence the GHG-emission, because depending on the energy generation source, different virtual GHG emissions could be taken into consideration (oil, natural gas, photovoltaic, biomass, water, wind).

- Information technology: the up-to-date IT solutions can support the sustainability aspects and greening tendencies of supply chain solutions. The Internet-of Things technologies of the fourth industrial revolution make it possible to transform conventional supply chain solutions into cyber-physical systems, where the greening tendencies can be supported by IT solutions including cloud computing, fog computing, edge computing, big data, digital twin for forecasting, identification and tracking solutions.

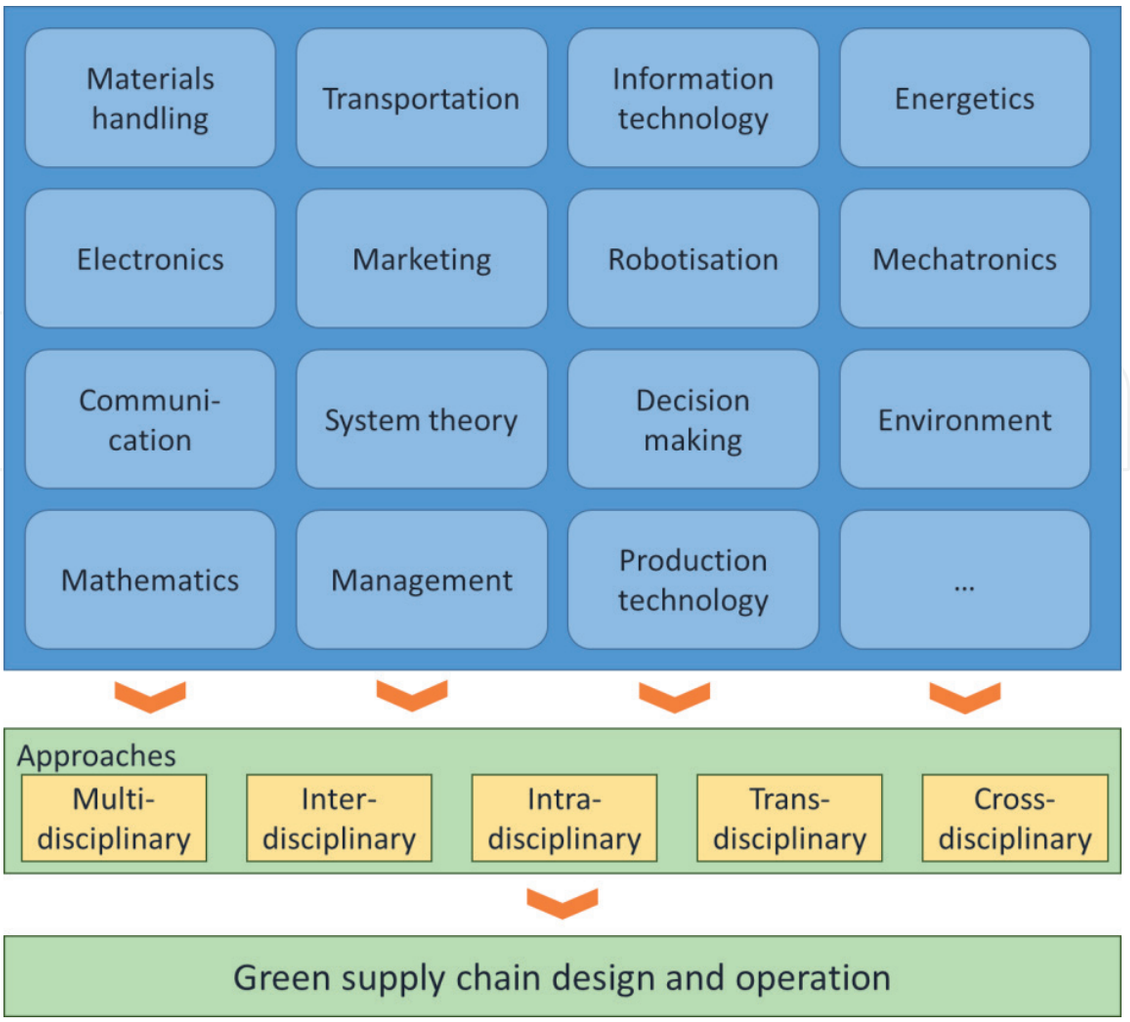

Figure 4.
Disciplinarities in the design and operation of green supply chain solutions.

- Energetics: the reduction of energy consumption and emission is in the focus of the energetics of green supply chain, but other aspects (clean technology and waste reduction in production, combined transportation and green containers and packaging in distribution, recycling and reuse in inverse processes, sustainable raw materials and low pollution in procurement) also have to be taken into consideration [29].

- Marketing: Building a green supply chain requires not only green production and logistics processes, but also green marketing, especially from the international global sourcing and distribution point of view. We cannot overlook the impact of green and sustainable marketing on green supply chain management [30, 31].

- Robotisation: Robots, autonomous robots and drones, as important tools of the fourth industrial revolution, represent promising opportunities and potentials for the improvement of green aspects of supply chain solutions. The key success factors of the robotisation are the followings: application of artificial intelligence in robot control, navigation, cost reduction regarding investment and operation, application of advanced sensor technology. From drones point of view regulatory aspects and public policies play important role [32].

- Mechatronics: Mechatronics has a great potential to create sustainable businesses, because of its pivot ability in manufacturing, assembly and

disassembly. Mechatronics in production offers flexible machinery equipment, which with cooperation of in-plant logistics and purchasing lead to the fulfilment of dynamically changing demands of customers.

- Communication: The communication aspects in supply chain management can be realized both in macro- and micro-level. Macro-level communication is represented by strategic and tactical level, where the players are stakeholders, suppliers, manufacturers, distributors and customers, while the micro-level communication is important on the operative level (within and between purchasing, productions, distribution and reverse processes).

- System theory: The interdisciplinary research of green supply chain solutions, as complex systems can be broken into different approach, depending on the complexity and dimensions of green supply chain solutions: we can use game theory, nonlinear dynamics, collective behaviour, network theory or pattern formation to support the optimal design and operation of green supply chain solutions or make greener a conventional supply chain.

- Decision making: Complex decision-support models and decision-making methods have a great impact on the design and operation of green supply chains, because these models make deal with multiple dimensions, objective functions and constraints of sustainability [33].

- Mathematics: The complexity of today's supply chain solutions is permanently increased. The design and optimization of these complex systems and processes can be supported with high-performance algorithms, especially in the case of NP-hard optimization problems, where the application of heuristics and metaheuristics offers a potential way for the solution of design- and operation-related optimization problems.

- Production technology: The sustainable energy and climate technologies are important not only for energy-intensive technologies represented by steel or paper industry, but also they play important role in all sectors of industrial production. Greening of production and greening of logistics are twins, they are drivers of the green innovation together.

Integrated approach. Today, a multidimensional view of the problem of respecting the environment is thinking in terms of the product life cycle (LCA - Life Cycle Thinking). This is a key concept for the sustainable production and consumption of resources. Life Cycle Assessment covers all processes from resource extraction through production, delivery, consumption, recycling or disposal management to the end of a product's life. Life Cycle Assessment was formalized by the International Organization for Standardization (ISO) in Geneva, Switzerland. LCA is based on an iterative process consisting of four steps, definition the goal and scope, resource analysis, impact assessment, evaluation. In this approach, not only the primary energy of the product production is important, but also the later phases of the life cycle, including the product use phase or post-consumption product development [34]. Energy recovery from combustion or raw material exchange as a result of recycling of tested products is also taken into account. Thanks to this, it is possible to reduce the environmental impact at this stage of the product life cycle, where it is possible to most effectively reduce it and at the same time limit it by using appropriate tools and techniques [35].

Infuence of transport. The choice of means of transport in the supply chain is an important issue that requires operator attention. For freight transport the average CO_2 emissions in grams per tonne-kilometer is:

- for sea transport: 29 g/tkm,
- for rail transport: 41 g/tkm,
- for road transport: 207/g tkm,
- for air transport: 450 g/tkm.

Based on these works [36–38], it is possible to assess the impact of individual modes of transport on the environment. Under the criterion of CO2 emissions to the atmosphere, the greatest damage is done by the aviation industry, particularly over short distances below 1000 km, such flights with jet engines should generally be prohibited. Moreover, the negative impact of contrails on the environment and global warming has not been fully recognized in aviation to this day. Toxic additives formed as a result of burning aviation fuels in the upper atmosphere, effectively shade solar radiation and are very difficult to dispose of.

5. Conclusion

The design and operation of green supply chains is a complex problem, which can be realized using different disciplinarities. Within the frame of this chapter the authors give a short overview of knowledge and their application as disciplinarities, including trans-, inter-, intra-, multi- and crossdisciplinarity. As a managerial impact, we would like to mention that the application of the described disciplinarities can lead to different result, therefore it is important to choose the best team and the best approach for the design and operation of green supply chain solutions. A further study of this introductory chapter would be a deeper analysis of the mentioned disciplinarities. Another research direction is to develop an analysis method, which makes it possible to measure the effect of the different disciplinarities and approaches on the performance of the green supply chain solutions.

Conflict of interest

The authors declare no conflict of interest.

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