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Green Supply Chain
Competitiveness and Sustainability

Edited by Tamás Bányai and Ireneusz Kaczmar

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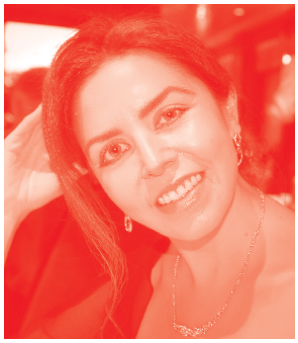

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Meet the editors

Tamás Bányai received a master's degree in 1993 and a Ph.D. in 1999 from the University of Miskolc, Hungary, where he is currently working as an associate professor. He has more than twenty-five years of teaching and research experience in the design and control of materials handling systems and supply chain management, with special emphasis on heuristic optimization of large-scale systems. He has published more than 150 research papers, book chapters and conference proceedings. He has been a member and manager of more than fifty national and international R&D projects. Away from academia, Dr. Bányai's other interests include playing the piano and taking photographs.

Ireneusz Kaczmar is an IT engineer with an MA in Economy. He received a Ph.D. in Economic Sciences from the Department of Management and Social Communications, Jagiellonian University, Cracow, Poland. Currently, Dr. Kaczmar lectures management classes at the Institute of Technical Studies, East European State University, Przemyśl, Poland, on topics such as mechatronics, transport and logistics engineering and IT in business. Scientifically, he is interested in quantitative research and the application of computer simulations in industries. He is a scholar of the Erasmus Programme and author of many national and international research articles.

Contents

Preface

This book offers a selection of chapters in the field of green supply chain management, promoting new research results in the field. Authors from South Africa, Ghana, Jordan, Cameroon, Syria, Poland and Hungary published worked examples and case studies resulted from their research in the field. Implementing Industry 4.0 technologies and solutions in supply chain solutions is a strategic objective of the economy to foster competitiveness on the global market, while environmental aspects also must be taken into consideration. The integration of eco-friendly aspects, tools and solutions into a conventional supply chain lead to environmental friendly global processes in the manufacturing and service industry.

The book covers six topics, determined by the theoretical and practical aspects of green supply chain solutions.

Chapter 1, "Introductory Chapter: Disciplinarity Aspects in Green Supply Chain Design and Operation": The design and operation of supply chain integrate a wide range of disciplinarities. This chapter describes the available types of disciplinarities, focusing on interdisciplinarity, multidisciplinarity, crossdisciplinarity, transdisciplinarity and interdisciplinarity regarding green supply chain design and operation research.

Chapter 2, "Green Supply Chain Management Practices and Firm Characteristics: Evidence from Cameroon": Using a case study, this chapter analyzes the main aspects of sustainability and green practices using the Business Climate Survey. The descriptive and econometric analysis demonstrates the main differences between green firms and non-green firms. As main differentials, factors such as regulatory framework, skilled workers, turnover exporting activities and firm size were identified.

Chapter 3, "Green Transportation in Green Supply Chain Management": Green transportation represents a very important sector of green supply chain management. Transportation processes are core activities in purchasing, production, distribution and inverse processes, therefore their optimal design and operation is a potential way to sustainable value-making chains. It is revealed that most international markets prioritize the emission of gas, rather than focusing on implementing green technologies in transportation. This chapter identifies major trends in green transportation, slow steaming, voyage optimization and efficiency in port operations.

Chapter 4, "Green Supply Chain in Solid Waste Management: Case Study of EcoCare H2H Waste Collection, Goaso, Ghana": This chapter analyzes the levels of green supply chain management applications in solid waste management focusing on a house-to-house waste collection model. It also examines the social, environmental and economic impacts of EcoCare and H2H Waste Collection initiatives. The authors recommend a private-public cooperation. This partnership could improve solid waste collection processes and lead to greener cities.

Chapter 5, "Green Initiatives in Supply Chain Management Drives Enterprises' Competitiveness and Sustainability": Industry 4.0 technologies make it possible to integrate partners of supply chain processes for faster, reliable and visible processes. The development of green initiatives in the field of manufacturing and services requires the improvement of supply chain processes, especially in the field of procurement, production, packaging, product sales and marketing, logistics and product life management. This chapter discusses the main aspects of technology, competitiveness, risk, disruptions, and lean and agile approaches.

Chapter 6, "The Impact of Industry 4.0 on the Future of Green Supply Chain": The transformation of conventional supply chain solutions into cyber-physical supply chain makes it possible to increase the performance of the value-making chain, while sustainability aspects can be taken into consideration. This chapter describes available Industry 4.0 technologies and summarizes their potentials.

The aim of this book is to help students as well as managers and researchers to understand and appreciate the concept, design and implementation of green supply chain solutions.

The editors thank the chapter authors for their scientific contributions. The chapters were edited and published following a rigorous selection process. We also wish to thank and acknowledge the many individuals who helped us throughout the editorial process that made this book possible.

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Chapter 1

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

Tamás Bányai and Ireneusz Kaczmar

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**.

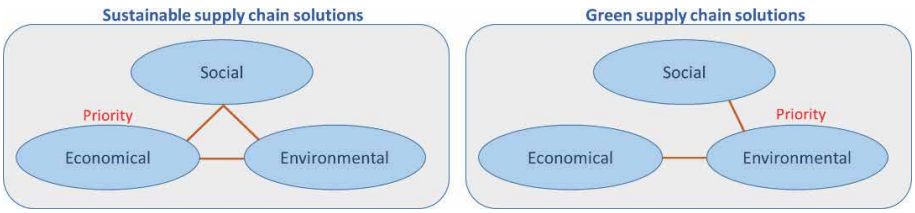

Figure 1.
Sustainable supply chain versus green supply chain.

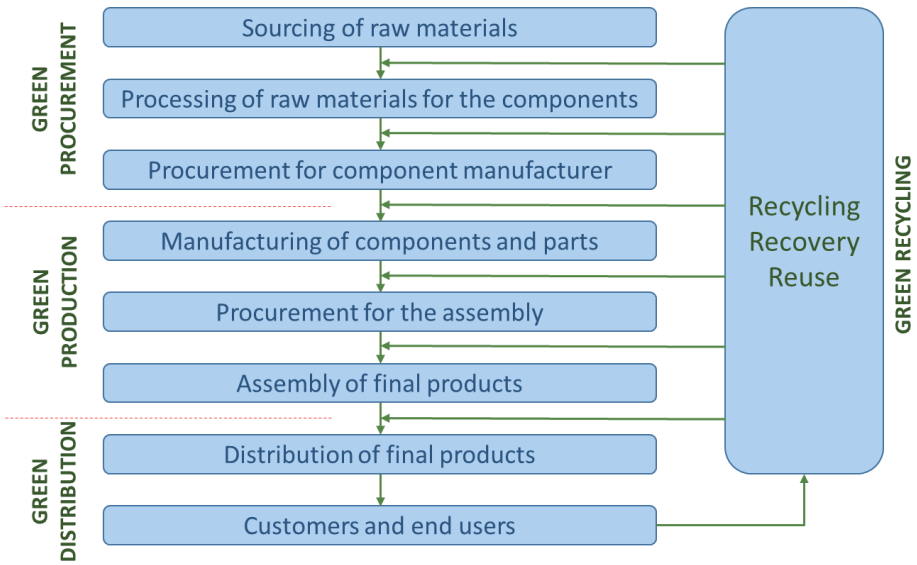

Figure 2.
Simplified process of green supply chain.

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

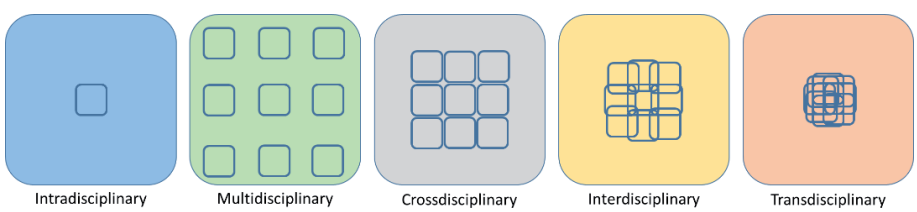

Figure 3.
Different types of disciplinarities by Jensenius [12].

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.

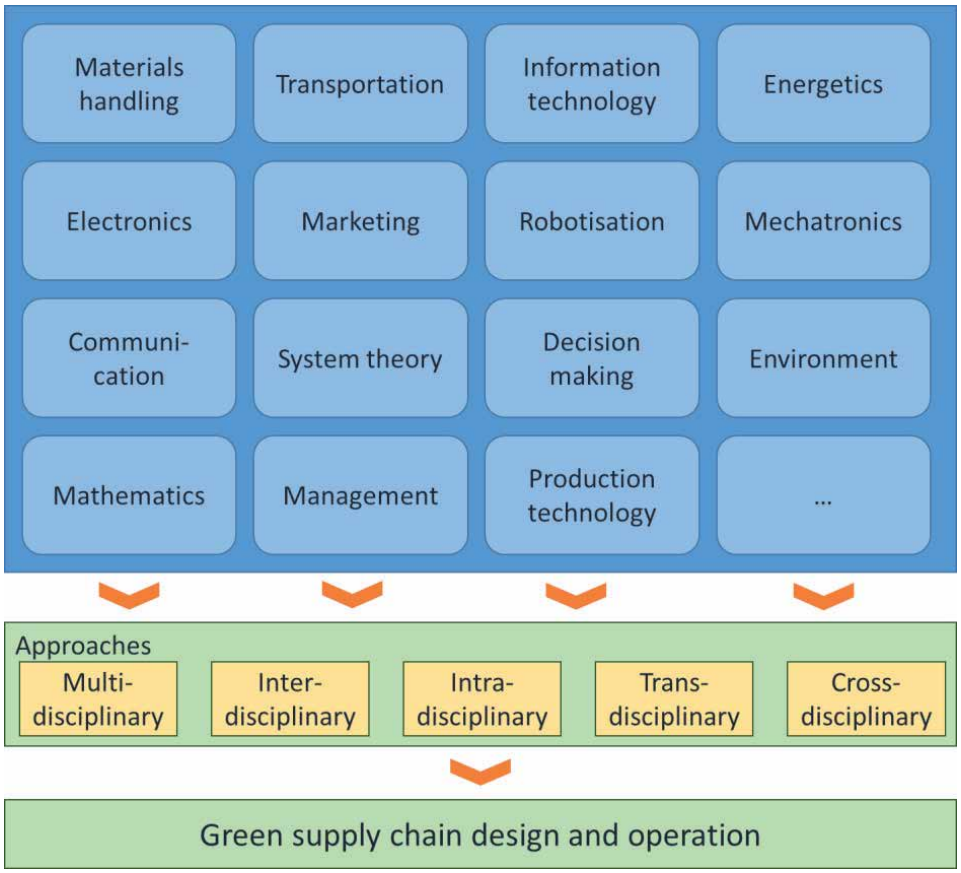

Figure 4.
Disciplinarities in the design and operation of green supply chain solutions.

- 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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References

[1] Srivastava SK. Green supply-chain management: A state-of-the-art literature review. International Journal of Management Reviews. 2007;9:1:53-80. DOI 10.1111/j.1468-2370.2007.00202.x

[2] Hervani AA, Helms MM, Sarkis J. Performance measurement for green supply chain management. Benchmarking: An International Journal. 2005;12:4:330-353. DOI 10.1108/14635770510609015

[3] Christopher M.: Logistics and supply chain management: Strategies for reducing costs and improving service, Financial Times – Prentice Hall, London, 1998.

[4] Younis H., Sundarakani B., Vel, P.: The impact of implementing green supply chain management practices on corporate performance. Competitiveness Review, 2016.

[5] Witkowski J., Pisarek A.: Istota zielonych łańcuchów dostaw propozycja systematyzacji pojęć. Studia Ekonomiczne, 315, 11-26, 2017.

[6] Nowicka K.: Zielone łańcuchy dostaw 4.0. Polityka klimatyczna i jej realizacja w pierwszej połowie XXI wieku, CMS, Sopot, 2020.

[7] Szmelter A.: Specyfika zarządzania zamkniętą pętlą łańcucha dostaw w sektorze spożywczym. Logistyka Odzysku, 3(20), 20-26, 2016.

[8] Baran J.: Life Cycle Approach-based Methods-Overview, Applications and Implementation Barriers. Zeszyty Naukowe. Organizacja i Zarządzanie Politechnika Śląska, 136 Modernity of Industry and Sciences, 9-23, 2019.

[9] Cooke SJ et al. Diverse perspectives on interdisciplinarity from Members of the College of the Royal Society of Canada. Facets. 2020;5:138-165. DOI 10.1139/facets-2019-0044

[10] Zeigler EF. Don't forget the profession when choosing a name! In The evolving undergraduate major. Edited by CB Corbin and HM Eckert. 1990. Human Kinetics, Champaign, Illinois. pp. 67-77.

[11] Rodgers P, Bremner C. Alterplinarity - "alternative disciplinarity" in future art and design research pursuits. Studies in MaterialThinking. 2011;6:1-17.

[12] Jensenius AR. Disciplinarities: intra, cross, multi, inter, trans. Available: https://www.arj.no/2012/03/12/disciplinarities-2/ Accessed: 30/06/2021

[13] Gutt J. et al. Cross-disciplinarity in the advance of Antarctic ecosystem research. Marine Genomics. 2018;37:1-17. DOI 10.1016/j.margen.2017.09.006

[14] Renn O. Transdisciplinarity: Synthesis towards a modular approach. Futures. 2021;130:102744. DOI 10.1016/j.futures.2021.102744

[15] Sibilla M, Kurul E. Transdisciplinarity in energy retrofit. A Conceptual Framework. Journal of Cleaner Production. 2020;250:119461. DOI 10.1016/j.jclepro.2019.119461

[16] Bixler RP, Atshan S, Banner JL, Tremaine D, Mace RE. Assessing integrated sustainability research: use of social network analysis to evaluate scientific integration and transdisciplinarity in research networks. Current Opinion in Environmental Sustainability. 2019;39:103-113. DOI 10.1016/j.cosust.2019.08.001

[17] Balsiger J. Transdisciplinarity in the class room? Simulating the co-production of sustainability

knowledge. Futures. 2015;65:185-194. DOI 10.1016/j.futures.2014.08.005

[18] Lahiri S, Snowden B, Gu J, Krishnan N, Yellin H, Ndiaye K. Multidisciplinary team processes parallel natural disaster preparedness and response: A qualitative case study. International Journal of Disaster Risk Reduction. 2021;61:102369. DOI 10.1016/j.ijdrr.2021.102369

[19] Jia L, Gao Q, Liu Z, Tan H, Zhou L. Multidisciplinary fault diagnosis of complex engineering systems: A case study of nuclear power plants. International Journal of Industrial Ergonomics. 2020;80:103060. DOI 10.1016/j.ergon.2020.103060

[20] Maniscalco M, Fuschillo S, Ambrosino P, Martucci M, Papa A, Matera MG, Cazzola M. Preexisting cardiorespiratory comorbidity does not preclude the success of multidisciplinary rehabilitation in post-COVID-19 patients. Respiratory Medicine. 2021;184:106470. DOI 10.1016/j.rmed.2021.106470

[21] Szabó AA, Illés B, Bányai Á. Industry 4.0 and logistics 4.0 - intelligent designs in FMCG logistics. Advanced Logistic Systems: Theory and Practice. 2020;14:1:14-24. DOI 10.32971/als.2020.005

[22] Veres P. The importants of clustering in logistic systems. Rezanie i Instrumenty v Tekhnologicheskih Sistemah. 2021;94:1:11-18. DOI 10.20998/2078-7405.2021.94.02

[23] Vida L, Illés B, Bányai Á. Preventing the negative effects of the covid-19 epidemic in international freight transport. Advanced Logistic Systems: Theory and Practice. 2020;14:1:5-13. DOI 10.32971/als.2020.004

[24] Erdei L, Illés B, Tamás P. Analysis of train control system standardization. Journal of Production Engineering. 2020;23:1:35-38. DOI 10.24867/JPE-2020-01-035

[25] Cservenák Á. Path and trajectory planning for an automated carrier vehicle equipped with two conveyor belts used in manufacturing supply. Manufacturing Technology. 2021;21:2:163-182. DOI 10.21062/mft.2021.027

[26] Cservenák Á. Simulation and modeling of a DC motor used in a mobile robot. Academic Journal of Manufacturing Engineering. 2020;18:4:183-190.

[27] Bhandari BP, Dhakal S. A multidisciplinary approach of landslide characterization: A case of the Siwalik zone of Nepal Himalaya. Journal of Asian Earth Sciences: X. 2021;5:100061. DOI 10.1016/j.jaesx.2021.100061

[28] Li N, Zhao L, Bao C, Gong G, Song X, Tian C. A real-time information integration framework for multidisciplinary coupling of complex aircrafts: an application of IIIE. Journal of Industrial Information Integration. 2021;22:100203. DOI 10.1016/j.jii.2021.100203

[29] Khan SAR, Qianli D. The environmental supply chain management and the companies' sustainable development. Advances in Social Science, Education and Humanities Research. 2017;99: 125-129.

[30] Chan HK. Supply Chain Systems – Recent Trend in Research and Applications. IEEE Systems Journal. 2011;5:1:2-5. DOI 10.1109/JSYST.2010.2100191

[31] Hing KC, Hongwei H, Wang WYC. Green marketing and its impact on supply chain management in industrial markets. Industrial Marketing Management. 2012;41:4: 557-562. DOI 10.1016/j.indmarman.2012.04.002.

[32] Fitzgerald J, Quasney E. Using autonomous robots to drive supply chain innovation A series exploring Industry 4.0 technologies and their potential impact for enabling digital supply networks in manufacturing. Available: https://www2.deloitte.com/ Accessed: 3/07/2021

[33] Banasik A, Bloemhof-Ruwaard J, Bloemhof-Ruwaard J, Kanellopoulos A, Claasen GDH, Van der Vorst J. Multi-criteria decision making approaches for green supply chains: a review. Flexible Services and Manufacturing Journal 2018;30(3):1-31. DOI 10.1007/ s10696-016-9263-5

[34] Pesonen H-L.: Environmental Management of Value Chains. Promoting Life – Cycle Thinking in Industrial Networks, University of Jyväskylä, Finland, 2001.

[35] Manfredi S. Pant R.: Supporting Environmentally Sound Decisions for Waste Management. A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA), JRC Institute for Environment and Sustainability, Luxembourg, 2011. DOI 10.1007/ s11367-011-0315-5

[36] Witaszek M.: Porównanie emisji zanieczyszczeń powietrza przez różne gałęzie transportu, Politechnika Śląska, 2007.

[37] Eickman C.: Pomiary emisji CO2 metody porównawcze w transporcie drogowym i kolejowym, Eksploatacja, 2003.

[38] Report European Aviation Environmental, EASA, EEA, EUROCONTROL, Luxembourg, 2019.

Chapter 2

Green Supply Chain Management Practices and Firm Characteristics: Evidence from Cameroon

Manfred Kouty

Abstract

Since the beginning of the twentieth century, green supply chain management (GSCM) has emerged as a set of managerial practices that integrate environmental issues into supply chain management. The purpose of this study is to investigate the firm characteristics and factors that could affect the use of green practices by the firm in Cameroon. Using the Cameroon Business Climate Survey (BCS) for the year 2016, our analysis shows that there exist substantial differences between the green firms and non-green firms. These differentials include factors such as size and skill workers. We also find some evidence that regulatory framework, skill workers, turnover exporting activities and firm size are consistent variables that influence whether a firm will use green practices in Cameroon.

Keywords: GSCM practices, firms, performance, Cameroon

1. Introduction

Since the Rio Earth Summit in1992, sustainability development has become an important issue and a common preoccupation on both national and international levels. The growing importance of this concept is due mainly to the overexploitation of the planet's resources, the continuous degradation of the environment and its consequences on climate change [1].

The concept of sustainability development is generally understood as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. Elkington [2] has operationalized the concept of sustainability development using the concept of triple bottom line, which integrates economic, environmental and social sustainability.

The integration of sustainability into supply chain management (SCM) has led to the development of the concept of sustainable supply chain management (SSCM), broadly defined by Carter and Rogers as the 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 [3].

When dealing with environmental issues, enterprises and academics refer to green supply chain management (GSCM) that aims to reduce harmful effects to the environment [4, 5]. The GSCM practices include many aspects of SCM as product

design, material sourcing and selection, manufacturing processes, delivery of the final product to consumers as well as the end-of-life management of the product after its useful life.

Today, the issue of GSCM is very important to firms because an increasing number of their customers and businesses are choosing safe and environmentally friendly products when making a purchase decision. Around the world, a growing number of firms have already embodied green elements in their business activities [6, 7]. However, some firms are confronted with various challenges in formulating and implementing their green business strategies [8].

Despite the abundant literature exploring the relationship between business and the environment [4, 9], little research attention has been devoted to the sub-Saharan African cases. Against this background, the aim of this study is to develop the research in the area of GSCM by investigating the characteristics of green firms and factors influencing the adoption of green practices in Cameroon. In particular the study seeks to answer two key questions: What are the characteristics of green firms in Cameroon? What factors are driving Cameroonian's firms to become more green?

The answers on these questions can be useful in order to develop the appropriate GSCM practices and reducing the environmental problems in Cameroon.

The rest of the paper proceeds as follows. The next section presents the short overview of environmental policies in Cameroon. This is followed by a brief review of the literature. The empirical analysis and results are presented in Section 4. Section 5 concludes with a discussion of policy implications.

2. Short overview of environmental management policies in Cameroon

From the biodiversity point of view, Cameroon has one of the richest and most diverse faunas on the African continent and ranks in the fifth rank. The country also owns one of the largest forests in Africa, which cover 22.5 million hectares.

Like other African countries, Cameroon faces many environmental problems: soil degradation and desertification, loss of biodiversity due to deforestation and hunting, industrial pollution and urban management.

Despite the consideration of the environment as a precious asset that must be preserved for present and future generations by the public authorities, it's only after the 1992 Earth Summit that a clear environmental policy is defined in Cameroon. Cameroon has signed the 1992 Convention on Biological Diversity (CBD), which provides the framework for global action on biodiversity. The strategic approach of the CBD to safeguard biodiversity and its benefits is defined by the 2011–2020 Strategic Plan.

The law relating to environment is adopted in 1996. This law encourages the participation of the population in the protection of the environment and leads to the establishment of specialized ministries and institutions. With regard to the institutional mechanism, two ministers are created: the Ministry of Environment, Nature Protection and Sustainable Development (MINEPDED) and the Ministry of Forest and Wildlife (MINFOF). The MINEPDED is responsible for the development, implementation and assessment of the government's policy on the environment, nature protection and sustainable development. The MINEPDED has been entrusted with the implementation of the National Environmental Management Plan (PNGE), a general framework of reference for the various sectoral environmental management actions in Cameroon.

The MINFOF plays a leading role in the fight against climate change is the Ministry of Forest and Wildlife. For this aim, the MINFOF has developed the

National Observatory on Climate Change (ONACC) and the National Forest Development Plan (PNDF) and the National Agency for Forest Development Support (ANAFOR). The ONACC's missions are to monitor and evaluate the socio-economic and environmental impacts of climate change and to propose preventive measures, mitigation and/or adaptation to the adverse effects and risks associated with these changes. The PNDF includes measures to reduce emissions from deforestation and forest degradation. The ANAFOR's role is to regenerate the forests.

Thanks to the ONACC's actions, thousands of hectares of Cameroon's forests are now classified as "protected areas", which allows them to be preserved and, at the same time, to reduce related emissions.

From the business point of view, the environmental law contains the incentive measures to promote the ecologically innovative firms and sanctions. For example, Article 76 of the law relating to the environment states that the industrial establishments importing equipment enable them to eliminate greenhouse gases like carbon dioxide and chlorofluorocarbons, in their manufacturing process or their products, or to reduce any form of pollution benefit from a reduction of custom duty on these equipment. Private individual and corporate bodies promoting the environment shall benefit from a deduction on taxable profit.

3. GSCM practices and firm characteristics: what does the literature says?

Extensive literature reviews can be found in [4, 5, 10, 11]. We summarize briefly the typology of GSCM practices and discuss the empirical studies.

According Azevedo et al. [12], the GSCM practices can be defined as any action performed across the supply chain, either within the company or involving external partners, to eliminate or reduce any kind of negative environmental impact. In this view, the "green enterprises" are those which contribute to preserving or restoring environmental quality, protect ecosystems and biodiversity and operate in a way that solves rather than causes environmental problems [7]. These enterprises also reduce energy, material and water consumption through high-efficiency strategies.

Within the literature, there are several factors that motivate firms to adopt GSCM practices or to go "green" [5, 9, 13–15]. These factors can be grouped in two strands: the internal factors and external factors [7, 10].

3.1 The external factors

The external factors are highlighted by the institutional theory and supply chain models [16].

According to the institutional theory, there is a connection between GSCM practices in an organization and external forces, such as regulatory systems, market characteristics, communities and environmental interest groups and industry associations [17, 18]. The government rules through incentives and sanctions motivate firms to apply the green practices in their supply chain. In the same vein, the pressures exerted by the competitors' and the consumers' sanctions (boycotting) do indeed enhance environmental management practices in many firms [10].

In the supply chain models, the diffusion of environmental practices can be also explained with reference to the existence of power asymmetries within the supply chain [19]. In fact, the governance into supply chain is characterized by the authority and power relationships between firms. Thus, firms with strong bargaining power in the supply chain can exercise control over weaker parties and impose some [20, 21].

Empirically, many studies confirm the positive effect of the external factors on GSCM practices. For example, Liu et al. [22] find, in the case of construction sector, that the incentives from the government appear to be the main motivation for the use of green practices. Simpson and Power [23] also find that collaboration between the buyer and the supplier to achieve environmental management goals is potentially an effective way for a customer to introduce environmental performance requirements, environmental innovation activity and environmentally sound process technologies into the supply chain.

Gimenez and Sierra [24] find that the higher the level of implementation of environmental monitoring and collaboration, the higher the environmental performance.

3.2 The internal factors

The theory of transaction cost economics (TCE) and the resource-based view (RBV) theory can be used to explain how internal characteristics of the firms (management structure, governance and firm resources) influence their ability to be "green" [6, 25].

According to the TCE, the information costs associated with learning about new technologies, ideas and competitive landscapes and even determining the costs of acquiring competency in a given arena can impact the ability of the firms to adopt the environmental practices [26].

The resource-based view developed by Wernerfelt [27] perceived a firm as a broader set of resources compared to the traditional view which accounts only for categories such as labour, capital and land. The resources a firm possesses can provide a source of competitive advantage [28]. As Leonidou et al. [10] show, many firms can develop a reluctant attitude to environmental issues, mainly because of: (a) The high level of uncertainty involved in introducing diverse programs and activities that are beyond their conventional range of activities; (b) The large financial investments required for various environmental programs and the relatively long time that has to elapse for them to yield a satisfactory return; (c) The high complexity associated with the need to coordinate all functional areas within the organization, as well as to collaborate with the different members of the supply chain; (d) The lack of technical expertise, which is needed to introduce green-related technologies and processes; (e) The absence of an appropriate organizational structure and culture.

On the base of these two theories, Leonidou et al. [29] found that the possession of sufficient physical and financial resources is vital in designing and implementing effective green marketing strategies, although no significant impact was observed with regard to experiential resources.

Marcus and Geffen [30] found that the firm's internal capabilities (e.g. organizational learning and searching for outside talent, technology and ideas) can help to acquire external capabilities, which in turn are conducive in improving environmental performance. Palmer and Truong [31] show that the relationship between technological green product introduction and firm profitability is positive.

4. Green practices and firm characteristics: what does firm-level evidence show?

In this section we present, firstly, the detailed findings, organized in terms of firm characteristics and their green practices. Secondly by time, we regress

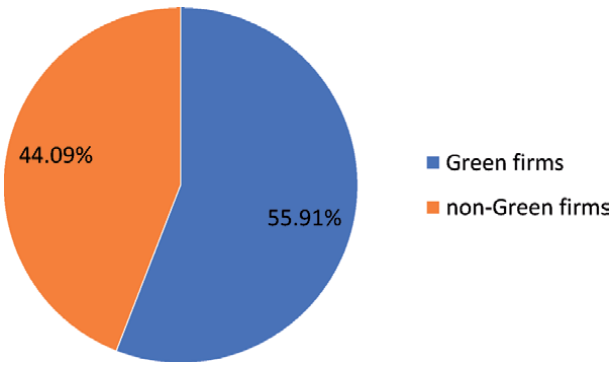

Figure 1.
Repartition of firms by status. Source: Author, based on BCS database.

the characteristics of firms on green practice variable in order to determine the firm characteristics that could influence the probability of the firms to use green practices.

The analysis is based on the firm-level microdata gathered by the Cameroon Business Climate Survey (BCS) 2016. The BCS database contains information of about 1585 enterprises from the ten regions of Cameroon. The dataset comprises of details on firm characteristics (firm size, firm age, legal status, industry), sales and supplies, capacity, business environment, etc.

Figure 1 presents the distribution of firms depending on the status (green or non-green firms). The green firms are those which adopt green (or environmental) practices.

A proportion of 55.91% of firms claim to have a green policy. This includes green practices such as reducing of carbon footprint, reducing and recycling waste, better office energy efficiency, the use of environmentally friendly materials and equipment, the implementation of a green training program for all employees, etc.

Figure 2 shows the spatial repartition of green firm in Cameroon and the distribution of green firms by size. Yaounde and centre and littoral regions appear to be less green (**Figure 2a**).

Green firms are concentrated in the regions where rural activities are dominant: Sud, Sud-Ouest and Est. According to the firm size[1], green firms are essentially large firms (**Figure 2b**). As documented in the literature, larger firms have the capacities in terms of skill, human and financial resources to invest in green measures and environmental innovations [7].

Sectoral and industry-wise categorization depicted in **Figure 3a** indicates that the primary sector has higher number of green firm than secondary and tertiary sectors. We also see that wood industry and services have higher number of green firms than others (**Figure 3b**).

The data also shows that the green firms are those which have high number of skill workers (**Figure 4**).

However, with the descriptive analyses conducted so far, it is impossible to determine the main characteristics which influence firms to adopt green practices. To address this issue, we conduct a regression analysis that allows us to assess how changing one factor influences the probability of a firm to be "green". We apply a simple probit model:

[1] The firm size is a function of number of permanent workers. Micro firms with employees <11; small firms with 11–50 employees; medium firms with 51–250 employees; large firms with employees >250.

$$pr(GSCMp=1)=\begin{pmatrix}\beta_0+\beta_1 legislation+\beta_2 turnover+\beta_3 skill\\+\beta_4 \exp ort+\sum_{i=5}^{8}\beta_i firmsize\end{pmatrix}+\varepsilon_i,$$

where the dependent variable "GSCMp" is set equal to 1 whenever the firm adopts green practices and 0 otherwise. As we mentioned above, the factors we consider to be relevant for the likelihood of a firm to be green are as follows.

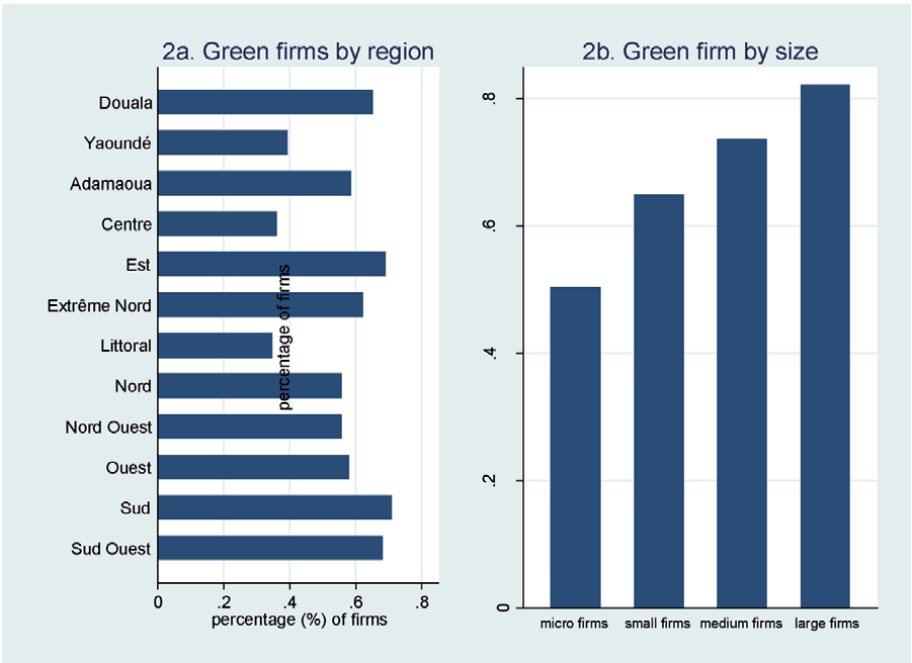

Figure 2.
Green firm by regions and size of the firms. Source: Author, based on BCS database.

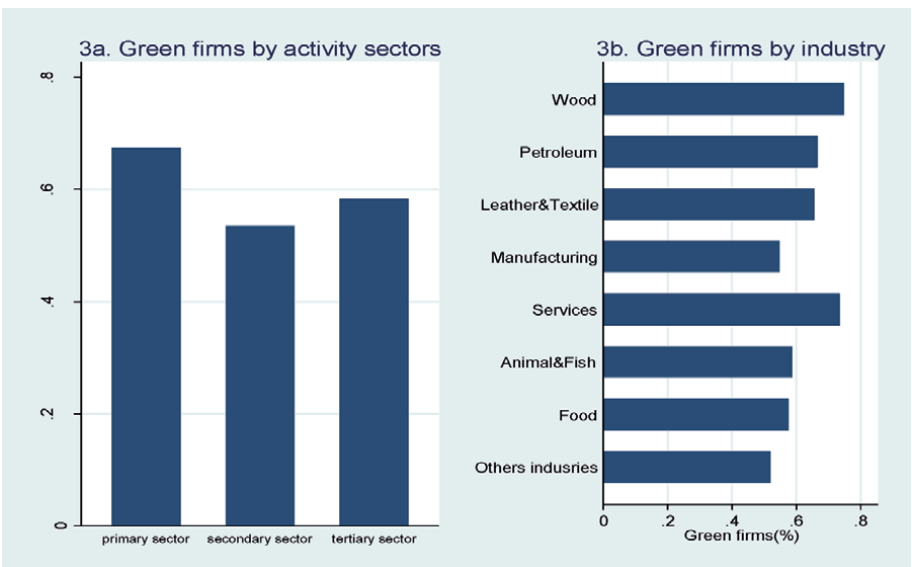

Figure 3.
Green firms by sector and industry. Source: Author, based on BCS database.

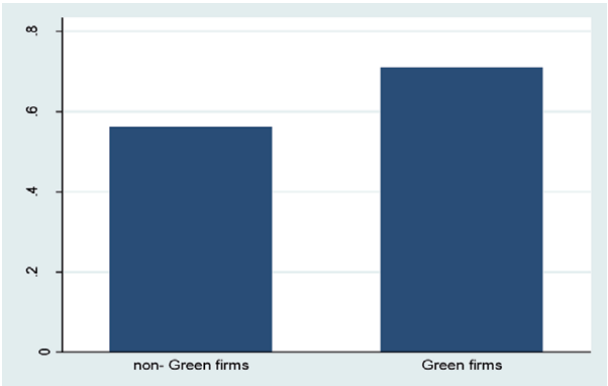

Figure 4.
Skill workers. Source: Author, based on BCS database.

First, we add an external factor of green practices as legislation. Second, we add the internal characteristics of the firms: turnover, skill workers, export (equal to 1 if the firm export and 0 otherwise) and firm size (four dummy variables, ranging from micro firms to large firms).

The detailed results are presented in **Table 1**. All the estimations are corrected for the heteroskedasticity. The results show that the external force such as legislation increases the likelihood of the firm to adopt green practices (Eq. (3)). These results are in line with the institutional theory, in which the regulatory framework governs a wide range of environmental issues, is usually associated with coercive measures and motivates firms to apply the green practices [16, 24, 32]. Gottberg et al. [33] also found that regulations and external stakeholders exert pressure on corporations to adopt GSCM practices.

The results also show that the internal factors such as skill workers, turnover and the export activity affect positively the probability to be green (Eq. (2)).

This result confirms the analysis of Leonidou et al. [29] who prove and found that the firm's internal capabilities (financial and human resources) are vital in designing and implementing effective green marketing strategies. Some green practices are quite costly to implement. Another important result is the export

	Eq. (1)	**Eq. (2)**	**Eq. (3)**
Legislation	0.317 (0.072)***	0.242 (0.074)***	0.242 (0.074)***
Skill workers		0.361 (0.071)***	0.336 (0.071)***
Turnover		0.026 (0.010)***	
Exporter		0.275 (0.130)**	
Small firm			0.340 (0.080)***
Medium firms			0.588 (0.154)***
Large firms			0.879 (0.286)***
Constant	0.052 (0.040)	−0.638 (0.178)***	−0.269 (0.061)***
Pseudo R^2	0.0097	0.0318	0.0420
Observations	1463.00	1439.00	1463.00

Note: The notations $^{*}p<0.1$, $^{**}p<0.05$ and $^{***}p<0.01$ denote significance at 10, 5 and 1% levels, respectively. The standard error in parenthesis is clustering on country.

Table 1.
Estimation results.

activity of the firm. The exportation increases the probability for the firms to adopt green practices. According to the learning-by-exporting hypothesis [34], exporting makes firms more productive. Firms that participate in foreign markets may acquire information from foreign customers and foreign contacts, who may suggest ways to improve the manufacturing process and new product designs and increase the quality of the goods. Exportation can benefit from an entirely green supply chain through cooperation with suppliers on green production technology and exchanging green information with them.

Finally, the size of firm influences positively whether the probability of firm to adopt green practices (Eq. (3)). Compare to large firms, small firms possess limited financial, human, technical and other resources that prevent them from undertaking environmental initiatives and implement proactive green strategies [10]. Larger firms have more incentives to use green practices.

5. Conclusion

In this study, we tried to identify whether there is a profile that differentiates green from non-green firms and determine the factors influencing the adoption of green practices in Cameroon. First, we used descriptive analysis and came to a conclusion that there exist substantial differences between the two groups of firms. These differentials include factors such as size and skill.

Second, we used econometric analysis to investigate the firm characteristics that influence the probability that firms adopt the green practices. We find some evidence that regulatory framework, skill workers, turnover exporting activities and firm size are consistent variables that influence whether a firm will use green practices.

The policy implications of our results for Cameroon are many. Since GSCM practices are connected to firm's size, it might be helpful if environmental policies give more incentives to small firms to use green practices.

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References

[1] Brundtland GH. Our Common Future. Bruxelles: Commission des Nations-Unies pour l'environnement et le développement; 1987

[2] Elkington J. Cannibals with Forks: The Triple Bottom Line of 21st Century Business. Oxford: Capstone; 1997

[3] Carter CR, Rogers SS. A framework of sustainable supply chain management: Moving toward new theory. International Journal of Physical Distribution & Logistics Management. 2008;**38**(5):360-387

[4] Green KW Jr, Zelbst PJ, Meacham J, Bhadauria VS. Green supply chain management practices: Impact on performance. Supply Chain Management: An International Journal. 2012;**17**(3):290-305

[5] Yang CS, Lu CS, Haider JJ, Marlow PB. The effect of green supply chain management on green performance and firm competitiveness in the context of container shipping in Taiwan. Transportation Research Part E: Logistics and Transportation Review. 2013;**55**:55-73

[6] Banerjee SB. Managerial perceptions of corporate environmentalism: Interpretations from industry and strategic implications for organizations. Journal of Management Studies. 2001;**38**(4):489-513

[7] Kasseeah H. Green measures and firm characteristics: Evidence from small businesses in an emerging economy. International Journal of Sustainable Development and World Ecology. 2020;**27**(1):55-64. DOI: 10.1080/13504509.2019.1676322

[8] Simpson M, Taylor N, Barker K. Environmental responsibility in SMEs: Does it deliver competitive advantage. Business Strategy and the Environment. 2004;**13**:156-171

[9] Srivastava SK. Green supply-chain management: A state-of-the-art literature review. International Journal of Management Reviews. 2007;**9**(1):53-80

[10] Leonidou LC, Christodoulides P, Kyrgidou LP, et al. Internal drivers and performance consequences of small firm green business strategy: The moderating role of external forces. Journal of Agricultural and Environmental Ethics. 2017;**12**(2):165-176

[11] Hallikas J, Lintukangas K. Purchasing and supply: An investigation of risk management performance. International Journal of Production Economics. 2016;**171**(Part4):487-494

[12] Azevedo SG, Carvalho H, Machado VC. The influence of green practices on supply chain performance: A case study approach. Transportation Research Part E: Logistics and Transportation Review. 2011;**47**(6):850-871

[13] de Giovanni P, Esposito Vinzi V. Covariance versus component-based estimations of performance in green supply chain management. International Journal of Production Economics. 2012;**135**(2):907-916

[14] Wang Z, Wang Q, Zhang S, Zhao X. Effects of customer and cost drivers on green supply chain management practices and environmental performance. Journal of Cleaner Production. 2018;**189**:673-682

[15] Yildiz Çankaya S, Sezen B. Effects of green supply chain management practices on sustainability performance. Journal of Manufacturing Technology Management. 2019;**30**(1):98-121

[16] Laari S. Green supply chain management practices and firm performance: Evidence from Finland.

In: Annales Universitatis Turkuensis. Finland: Turku School of Economics; 2016

[17] Delmas M, Toffel MW. Stakeholders and environmental management practices: An institutional framework. Business Strategy and the Environment. 2004;**13**(4):209-222

[18] Vachon S, Klassen RD. Environmental management and manufacturing performance: The role of collaboration in the supply chain. International Journal of Production Economics. 2008;**111**(2):299-315

[19] Sarkis J, Zhu Q, Lai K-H. An organizational theoretic review of green supply chain management literature. International Journal of Production Economics. 2011;**130**(1):1-15

[20] Crook TR, Combs JG. Sources and consequences of bargaining power in supply chains. Journal of Operations Management. 2007;**25**(2):546-555

[21] Nyaga GN, Lynch DF, Marshall D, Ambrose E. Power asymmetry, adaptation and collaboration in dyadic relationships involving a powerful partner. Journal of Supply Chain Management. 2013;**49**(3):42-65

[22] Liu Z, Geng Y, Lindner S, Zhao H, Fujita T, Guan D. Embodied energy use in China's industrial sectors. Energy Policy. 2019;**49**:751-758

[23] Simpson DF, Power DJ. Use the supply relationship to develop lean and green suppliers. Supply Chain Management: An International Journal. 2005;**10**(1):60-68

[24] Gimenez C, Sierra V, Rodon J. Sustainable operations: Their impact on the triple bottom line. International Journal of Production Economics. 2012;**140**(1):149-159

[25] Surroca J, Tribó JA, Waddock S. Corporate responsibility and financial performance: The role of intangible resources. Strategic Management Journal. 2010;**31**(5):463-490

[26] Tate WL, Dooley KJ, Ellram LM. Transaction cost and institutional drivers of supplier adoption of environmental practices. Journal of Business Logistics. 2011;**32**(1):6-16

[27] Wernerfelt B. A resource-based view of the firm. Strategic Management Journal. 1984;**5**(2):171-180

[28] Barney J. Firm resources and sustained competitive advantage. Journal of Management. 1991;**17**(1):99-120

[29] Leonidou LC, Leonidou CN, Fotiades T, Zeriti A. Resources and capabilities as drivers of hotel green marketing strategy: Implications on competitive advantage and performance. Tourism Management. 2013;**35**(2):94-110

[30] Marcus AA, Geffen D. The dialectics of competency acquisition: Pollution prevention in eclectic generation. Strategic Management Journal. 1998;**20**:1133-1156

[31] Palmer M, Truong Y. The impact of technological green new product introductions on firm profitability. Ecological Economics. 2017;**136**:86-93. DOI: 10.1016/j.ecolecon.2017.01.025

[32] Gimenez C, Sierra V. Sustainable supply chains: Governance mechanisms to greening suppliers. Journal of Business Ethics. 2013;**116**(1):189-203

[33] Gottberg A, Morris J, Pollard S, Mark-Herbert C, Matthew C. Producer responsibility, waste minimisation and the WEEE Directive: Case studies in eco-design from the European lighting sector. Science of The Total Environment. 2006;**359**(1-3):38-56

[34] Clerides S, Lach S, Tybout J. Is learning by exporting important? Microdynamic evidence from Columbia, Mexico and Morocco. Quarterly Journal of Economics. 1998;**113**:903-947

Chapter 3

Green Transportation in Green Supply Chain Management

Raeda Saada

Abstract

Organizations of the present day have directed their work patterns by acquiring the approach of green supply chain management (GSCM), in order to combat harmful environmental concerns. The most prominent reason behind the adoption of green strategy is to reduce the burden of the polluted environment. It is a concept which identifies the relationship between the supply chain operations and the natural environment. The present chapter provides a detailed discussion regarding the application of green transportation in green supply chain management, while shedding light to the evolution of green supply chain management, and its principle along with the factors that support total quality environmental management. The overall discussion is focused by elaborating the examples of green transportation in GSCM. The discussion revealed that most of the international markets prioritize the emission of gas, rather than focusing on implementing the green technologies in transportation. Slow steaming, voyage optimization, and efficiency in port operations are some of the major recent trends of green transportation identified in green supply chain management. However, some of the common examples of green transportation in GSCM Dalsey Hillblom Lynn (DHL) model of green transportation and Ingvar Kamprad, Elmtaryd Agunnaryd (IKEA) model of green transportation which serves as the major initiatives in the management of green transportation.

Keywords: green transportation, green supply chain management, environment, organizational operations, drivers and barriers, green energy

1. Introduction

Green supply chain management (GSCM) has acquired integrating importance for managing the organizational practices with environmental concerns. Some organization's supply chain managers still need to understand that reducing the environmentally harmful attributes will not only be beneficial for the society but will also improve their logistic operations [1]. The most important reason behind adopting the greening strategy in supply chain management is to reduce the burden of polluted environment caused by the wastage of industries. Undoubtedly, logistic operations have greatly contributed in raising the level of air pollution which affects both the environment and also the economy.

GSCM has been defined differently by various researchers, for instance, Sarkis [2] defined GSCM as the process where all the organizational operations and innovations related to supply chain management are deliberated in accordance with the environment, whereas, for Dwivedi [1], GSCM includes the fundamental industrial activities

such as material recycling, reusing, and substituting. Similarly, Shan and Wang [3] defined GSCM as a set of processes involving the activities of customer's and manufacturer's course of orders, product designs, procurement activities, distributions, and logistics while corresponding to the principles of eco-friendly environmental management [3]. Sharma et al. [4] explain the concept of GSCM as an integration of safe environment in designing products, sourcing and selection of material, production process, and final product delivery to the customers as well as disposal of wasted products.

According to Weeratunge and Herath [5], GSCM is the component which reflects the relationship of natural environment and supply chain operations. It further involves all the external or internal factors which influences the management operations of logistics and measures the performance of the supply chain process according to environmental aspects. Due to the extensive customer demands, organizations are shrinking to the core of Red Ocean and seek to establish new businesses or techniques to attract customers. In recent years, companies have shown an immense interest toward adapting the strategies of environmentally friendly methods by producing goods and services that meet the criteria of safe environment [5]. By shifting toward ecological systems, organizations can enhance the efficiency of production, achieving the competitive advantage and reducing the impact of harmful factors of the environment [4, 6].

2. The evolution of GSCM

According to Intravaia and Viana [7], environmental pollution issue has emanated exponentially since the 1960s. The reason behind this alarming situation was the absence of law specifically designed to manage environmental risks and damages, such as ISO 14000 which aims to manage and monitor the impact of environments. The concept of GSCM was contemplated in 1996 by the US Department of Manufacturing Research Consortium in the University of Michigan States. The main approach behind this concept was to regulate the environmental effects and resource allocation in the supply chain process [8]. The revolution of GSCM measures enhances the quality of services and makes the supply chain process cost efficient by implementing precautionary steps with respect to environmental safety [9].

In 2007, Turk institutions of economics and World Bank proposed the index containing the performance of logistic operations which evaluated the level of performance and development of different countries. This performance index was complied with various components such as customer's efficiency and management control, quality of transportation and infrastructure, logistic services, time frequency for shipment and delivery, tracing and tracking facility of the consignment, and ability to manage cost-efficient shipments [10].

The early concept to adopt the GSCM is to provide humans with the standard lifestyle by reducing the health risking hazards resulting in increased consumer trust [5]. According to Gandhi and Vasudevan [11], green management is considered as one of the significant practices to save the energy consumed during the supply chain processes. The revolution of GSCM resulted in spreading awareness about the environmental security, following which several industries are now implementing the waste-free and emission-free concept of energy. This implementation will help them to ensure the management of green environment for their customers who pay high concern toward global warming and climatic changes. Onurlubas [12] asserted that the evolution of green management has optimized organizations to pay more attention toward adopting the green practices to enhance the efficiency of environment. The reason behind this excessive concern is that consumers have

begun to question their practices with respect to their impact on climatic and environmental changes, thus, socially responsible and conscious organizations are revolutionizing their manufacturing processes by introducing and implementing green production strategies [3].

3. Principles of GSCM and green transportation

GSCM practices help in the reduction of elements which negatively impact the supply chain process. These practices bring along various financial or social benefits as well as environmental advantages [13]. Consumers have shown high interest toward the products of companies who work on ecologically friendly production and marketing activities.

Along with the integration of GSCM, organizations are highly focused on synthesizing the green transportation in their logistic operations. Transportation is currently the most prominent cause of increased global warming, health haphazard, and emission of gases. These problems have pressurized government to devise their policies for environmental safety in order to reduce the damage caused by the emission of greenhouse gases [14]. The broader concept behind the implementation of the green practices in supply chain management is to eliminate excessive use of material and production of carbon dioxide (CO_2) gas and abolish the use of recycled goods [6]. GSCM practices have also included many diverse dimensions such as the corporate engagements with the customers and suppliers which are helpful in integrating the green practices, green transportation, and reverse logistics [15].

Successful GSM practices are based on some important principles that revolve around useful practices resulting in high quality assurance and cost-effectiveness. These practices include as follows.

3.1 Green transportation

Globally, the demand for green transportation has been increasing rapidly. The purpose for initiating green transportation is the high emission of CO_2 gas since the 1990s, which is consequently risking the environment through freight transportation. It has increased with the percentage of 71% in 2016 and is anticipated to increase 50% more till the year 2050 [16].

Green logistics and green transportation have been the striking topics in today's manufacturing market. However, the acquisition of preventive measures among various countries included different strategies [10]. For example, Norway, Sweden, the United Kingdom, Switzerland, and Ireland have been working on the reduction of fuel and oil consumption to reduce environmental pollution [10]. The practices of green transportation and logistical reverse activities are the opportunities for organizations to boost their growth and reduce overall production costs. The efficiency of logistics can be further achieved by promoting the efficiency of transportation system, i.e., through green transportation [17].

3.2 Green procurement and logistics

Green procurement refers to the purchasing of products and services that are less harmful for the environment. The selection of the procurement is based on the quest of quality products and services that supports positive environmental and health concerns in competitive prices. In the early years of 2000, regulatory authorities amended their procurement standards by taking in environmental concerns

into account while purchasing goods and services. Most of the bureaux or departments were advised to refrain from using disposable items that are not eco-friendly and were motivated to purchase products that are developed through highly recycled content and maximum durability. Green procurement further includes products that are comparatively low in emitting toxic and poisonous substances [18]. It is a crucial step for any organizations to ensure that the purchasing of all their raw materials should be in accordance with the environmental objectives. The management of procurement and green purchasing are assigned to audit and inspect whether their supply chain department is implementing green practices in purchasing the raw materials and other purchase-related activities [15]. Generally, activities of green purchasing are complied with approaches including purchasing the goods or services that are environmentally friendly, evaluating products with internal and external auditors prior to their purchasing, or assisting the suppliers to enhance their functions in compliance with ecological goods and services [19].

Logistics on the other hand is considered as the most crucial factor in supply chain processes since it has acquired the most significant dimension for environmental impact. In logistics, the concept of green is applied to various elements such as raw material acquisition and transportation facility of outbound and inbound logistics [13]. The objective of green logistic is to eliminate the environmental effects in the logistical operations in order to achieve sustainable environmental, cultural, economic, and social advantages [10]. According to Franchetti et al. [19], there has been much debate on operations of green logistics, but industries of transportation have narrowed its definition. Its definition is compiled as the activities which involve the reduction of transportation cost and efficient utilization of assets, vehicles, distribution, and terminal centers.

3.3 Green warehouse

A number of green warehousing facilities are increasing promptly and shifting their operations to green practices which has also increased the cost and time allocation of the firms. The practices of managing the warehouses and inventories are the most crucial element of the logistic operations. This is simply defined as keeping the adequate amount of stock on the shelves and in the inventory, to prevent the wastage of material resulting in reduced transportation expenses and negative environmental impacts. The good inventory planning is referred to as reducing the wastage and efficiencies and decreasing the costs of tangible and intangible goods [13].

Many companies have realized the benefits of green warehousing and are keen to implement them in their supply chain process. Certain manufacturing industries have allocated these practices to minimize carbon consumption, environmental pollutions, and production cost, as well as to achieve the target of socially responsible organization [20].

3.4 Green design

Ecological or green designs are the set of activities which include the use of goods that are according to environmental discipline. An ecological design aims to establish a secure and clean factory with respect to reduced cost of disposal, health safety and minimum environmental risk factors [13], leading toward enhanced quality of services and products, cost-efficient production and while promoting a strong public image of brand and company. According to Ren et al. [21] by implementing eco-friendly practices, green design supply chain management can control about 80% of environmental impact, as Rostamzadeh et al. [20] asserted that it is associated with the overall flow of supply chain process.

3.5 Green manufacturing

Ecological production or green manufacturing is defined as the efficient production system which causes little to no pollution or wastage. The efficiency of any production facility could be measured by its ability to manufacture goods with minimal defection, scrap, or reworking on the material and its ability to manage the production of goods [13]. The ecological production in the supply chain process helps to diminish the negative effects of production and brings in the environmental sustainability throughout the production life cycle. It can also improve the manufacturing operations and financial performances of the organization [17]. Integrating the green manufacturing practices will also be beneficial in reducing the cost of raw material and transportation, by the expansion of environmental safety leading toward profitable growth and large market share.

3.6 Green marketing

Other names of ecological marketing are green marketing, social marketing, environmental marketing, or sustainable marketing. The term green marketing in the context of GSCM is defined as the activities that are designed to satisfy the needs of consumers in accordance with causing minimum risk to the environment [12]. This also encourages organizations to survive in competing international or national markets [20].

There are various green marketing practices that help to ensure that natural resources and raw materials are utilized to achieve the sustainability of environment. These practices include green designing of products, green product promotional campaigns, pricing according to green practices, targeting the green markets, and green positioning of the products [22].

3.7 Total quality environmental management

The concept of total quality management is based on achieving, maintaining, and ensuring the quality of the output. It is highly focused on continuous improvement of the business-related operations and prevents the chances of failure at each step of the production in order to successfully meet the needs and demands of consumers [23].

For the quality improvement processes, the International Organization for Standardization (ISO) was established in 1987 to ensure the contribution of organizations in environmental safety according to defined standards by the ISO. These standards included useful guidelines for the organizations to ensure the quality of their products and services according to its standards [24]. There are various in-house supply chain practices that are considered as an important discipline in GSCM. Among many internal practices, total quality management is notorious for managing the environmental security. These practices require upper management guidance as it is associated with the overall life cycle management [8]. The management of organizational total quality environment has broadened the GSCM concept to various operations including green designing of products as well as infrastructure, green procurements, ecological transportations (vehicles), eco-friendly logistics, and reverse logistics as well as recycling [15]. Diagrammatic Representations of the Working of Green Transportation in the Structure of Green Supply Chain Management (**Figure 1**). **Figure 2** provides a brief overview of the cycle of green supply chain process and its relation with green transportation.

Figure 1.
The Cycle of Green Supply Chain and Its Relation with Green Transportation.

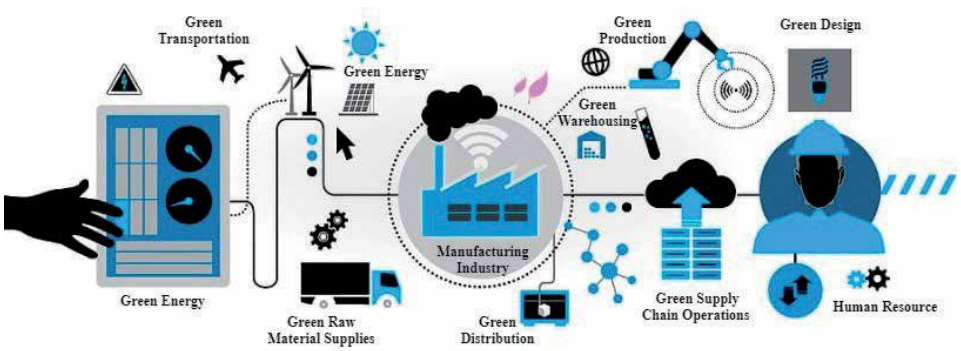

Figure 2.
The Functional Process of Green Transportation in GSCM.

4. Transportation types in supply chain management

The transportation in supply chain management was first developed through a railway transport in the nineteenth century. However, 1903 airway transports were introduced leading to the development of ocean/maritime transport in 1956, where cargo was delivered through containers via sea which gave a dramatic boom to water transportation.

Presently the concepts of supply chain management and transportation are broadly discussed and are referred to as operations that ensure the availability of goods and services when and where needed in adequate quantity [25]. In the international business world, transportation is the most dominating element in supply chain management as it influences the growth of business. Due to the intense demand of goods and services, delivering products to the end users or consumers has become the most crucial achievement for businesses.

It has been significantly noticed that, within the supply chain process, transportation plays the vital role in proving the efficiency and smooth flow of the operations. There are

various services of transportation management delivering the goods to the places where it is needed in demanded quantity. These services include air freight, road freight, railway freight, sea freight, pipeline freight, and services to and from warehouses [26, 27]. The real challenges that businesses face in transportation are feasibility and availability of viable roads to deliver goods. The most important operation in this challenge for the manufacturing industries is to optimize and modify their inventory and supply of the material in accordance to deliver the final product with the just-in-time system. This system helps to reduce the overall cost of facilities in maintaining materials required for production. Thus, today's supply chain process has become defying in meeting the long-distance consignments and ensuring the availability of supplies on time [28].

4.1 Modes of transportation

To reduce the cost of transportation and environmental risks, the quality of supply chain processes is enhanced through transportation modes such as intermodal and multimodal transportation. The intermodal transportation involves multiple modes to transport goods such as trucks, water, etc. Many organizations have shown a keen interest toward adopting the intermodal transportation in which products are transported through different medium of transportation. This mode of transportation in supply chain management has combined as one to provide the benefits such as efficiency in rail transport and flexibility in road freighting. The objectives of intermodal transportation are to reduce the emission of carbon and overall transport cost and to modify road congestion [29]. The intermodal transportation has minimized 57% of carbon emission as compared to other modes of transportation [30].

Multimodal transportation is quite similar to intermodal transport as it connects various transportation modes in a single process which ensures the cost efficiency in door-to-door goods movement under a single service provider [31]. The only difference in both modes is the number of units loaded for shipping [32]. There are further types of intermodal and multimodal transportations, which include as follows.

4.1.1 Air freight

Air transport is certainly the most expensive but the speediest freighting service among all other transportation types. It reduces the time of goods delivered to the doorsteps and is often preferred to transport the most valuable goods to the market. Bag mails, packages weighing 30 kg, and any document that could be carried through individual person are categorized as the smallest way of transportation. Globally air cargo is gaining an increasing role in international supply chain and logistics [31]. Due to the high cost of air cargo, most organizations use this mode as supplementary transportation service for the shipment of critical and urgently needed goods.

4.1.2 Road freight

Road transportation is relatively the most used type of transportation to deliver the goods via trucks, lorries, and trawlers. This is the most flexible mode, but it cannot be operated outside the roads. Road freighting is used by organizations where rapid distribution of light-weighted goods needs shipment in concise batches. The road transportation has become challenging as it has high maintenance costs of both carrier infrastructure and other repairing costs [31] and further affects environmental stability.

4.1.3 Railway freight

Railway transportation is relatively the cheapest and the least environmentally harmful mode of shipping the goods at distancing places. Globally, China

is recognized as among the best railway service providers. The railway system of China contributes 100% of transportation efficiency to the online marketing and product delivery [27]. Railway transportation offers skilled alternatives to road freight since its operations are partially lower cost and electrified which is economically and ecologically beneficial [29]. According to Romanow [28], railway freight, despite of its cost-efficient service, still lacks timely consignment deliveries. Thus, it is observed that without the adequate and necessary improvement in railway systems, pursuing consumers would be challenging.

4.1.4 Ocean freight

Since 1990, international trade occurs via ocean freight; this mode of shipment has risen to 65% which has driven the logistic managers with significant challenges in the selection of carrier to transport goods [33]. According to Dettmer et al. [29], the rates of transportations with the category of containerized products have been decreased exponentially since the last decade, making ocean freight as the cheapest mode of transporting products. Researchers such as Waller, Meixell, and Norbis [33] asserted that about 0% of the freights are transported via ocean as 25% of heavy products are delivered to international destinations. The most common ocean cargos include container ships, cargo vessels, oil tanks, bulk carriers, and general cargo ships. In a global logistics ocean, cargo vessels move ports to ports and are specialized for swift loading and unloading of the goods.

4.1.5 Pipeline

One of the important modes of transportation which has not been provided enough attention is the use of pipeline, which accounts for approximately $53 billion costs in the year 2018, specifically in the United States. The increased production of oil and gas has increased the usage of pipeline in the transmission of natural gas and oil. This has further increased the need of investments in the given area. The analysis indicated that the use of pipeline as the mode of transportation is limited and is still recognized as the small market in comparison to the overall size of the given mode of transportation [34].

4.1.6 Micromobility

Transportation modes such as e-bikes and e-scooters that are widely being used in the cities like New York and California are regarded as the eco-friendly transportation methods and are generally termed as micromobility. It is further recognized as the cheapest mode of transportation, when traveling approximately 5 miles or less, and is known to be the fastest and easy mode of transportation which does not require any license. One of the most significant characteristics of this mode of transportation is its eco-friendliness, as it does not operate through the burning of fuel [35].

4.1.7 Cable and drone

Another similar mode of transportation is the use of cable cars that are used in most of the mountainous regions. They serve as the effective mode of transportation which has met the limitations of time and cost. Hilly areas that are connected to the urban regions promote the use of cable cars as they provide them the socioeconomic benefit by reducing the barriers such as road traffic. Since they are environmentally friendly, the use of cable cars is highly promoted in various regions [36].

Another similar mode of transportation is the use of drone. The recent research conducted by the Lawrence Livermore National Laboratory (LLNL) [37] provided that the drone-based delivery is effective in reducing the emission of greenhouse gas and energy use in the transportation sector. The study further indicated that certain factors are considered in the successful use of drone. These factors include the size of the drone, the weight of the package, and the types of power plant deployed on the regional electricity grid. The use of drones is highly favorable in areas with relatively clean electricity like California [38].

5. Green transportation and its distribution

The widespread usage of green transportation has an additional scope in the distribution of goods, as it affects the quality of air, leading to additional noise generation. It further increases the chances of severe car accidents followed by its significant contribution to the global warming. According to Stern [38], in 2000, the transportation's share in the emission of global greenhouse gas was 14% which continued to grow in the succeeding years. However, following the advancement in e-commerce and the customer demands, a significant growth in the goods transportation has been observed. This has given rise to the strategic distribution of activities which offers smart solutions for the reduced carbon footprint of companies that have apparently developed a negative impact on the total costs as well as on individual life [39].

According to Ho et al. [40], the characteristics associated with the transportation are generally influenced by different factors such as shape, size, and materials. These factors are further important as they create a significant impact on the distribution process. However, better and strategically developed location patterns along with better packaging may serve as a prompt solution to overcome this impact, resulting in the decrease in amount and increase in space. The concept of green distribution can be classified under two categories, i.e., green packaging and green logistics [40].

5.1 Green packaging

The concept of sustainability is negatively affected by the increase in solid waste. Green packaging serves as the optimal solution to cater this challenge, as it is associated with the overall process of packaging life cycle [41]. Ninlawan et al. [42] provided additional information according to which green packaging can be further practiced by increasing the use of green packaging materials, promoting the reuse and recycling programs, or developing standardize methods of packaging. However, the control and management of the packaging system are held through the system evaluator indicators [43].

5.2 Green logistics

According to Jiange [41], green logistics is defined as the production and distribution of goods that are held in a sustainable manner by the inclusion of activities such as evaluation of the environmental influence of distribution methods used and reduction of the waste and its effective management along with the strategic planning of logistic activities. For Zhang and Liu [43], the development of the green logistics serves as an interconnected system and requires the cooperation of different parties including the common public, government officials, and corporate leaders. They added that the concept of green logistics is not a separate system; perhaps it is associated with the exchange of energy and information with the external world. The system is integrated through transportation and traffic, supervision and

management, and storage and delivery, along with the flow of information [41]. Green logistics majorly focuses on the direct delivery of goods to the user site, along with the bulk distribution of products rather than in small sets [42].

6. Examples of green transportation in GSCM

6.1 DHL model of green transportation

DHL is an international logistic organization operating worldwide business within 220 countries. DHL focuses on sustainability and CSR activities since 2009 and many campaigns for environmentally green initiative. *PPGoGreen* campaign program was launched to protect the environment to achieve sustainability and long-term improvement competence [44]. The vision of DHL is to develop green and sustainability in their transportation services by designing future goals to reduce the emission of greenhouse and carbon gases. Following these goals, DHL intended to enhance the efficiency in transportation by reducing carbon emission to 50%, resulting in reduction in pollution emission to 70%. DHL also initiated clean delivery and pickup services including electrified vehicles or bicycles and training suppliers and employees to follow the green transportation strategy of *Go Green* (Deutsche Post DHL Group).

6.2 IKEA model of green transportation

IKEA is one of the leading furniture manufacturers that have been working on maintaining sustainability in their overall logistic operations and committed to carry their operations with environment-friendly practices. IKEA has set vision for providing better lifestyle at home by promising high quality standards, low price, and environmental safety by not wasting natural resources. The founder of IKEA used to claim that furniture designers can design any desk within the cost of $1000 but designing a sustainable, functional, and beautiful for just $50 is marveling [32].

IKEA practices on green transportation by designing travel plans for their workers and logistic operations. The employees of IKEA are encouraged to travel through bicycles, walking, public busses, or sharing cars with their co-workers in order to support the company to achieve their vision [45]. From the transportation perspective, IKEA believes that utilizing loading shelves for transporting, the units will eliminate the space required for wooden pallets, which will reduce the overall cost of transportation. According to the sustainability report of 2019, gas emission through transportation is recorded to be 19.4% [46]. To reduce this, IKEA has set future goals to reduce 30% of greenhouse gases from their transportation services in 2020 [47] and further aims to eliminate the emission of carbon gases to 70% by 2030 [46].

7. Importance and benefits of green transportation

The practices of green transport have been on an exponential importance in green logistics. It has been identified that promoting green management and transportation has significant benefits toward economy, environmental well-being, as well as improving the organization's growth [10]. Green logistics and green transportation are important in reducing the consumption of fuel and energy as their target is to regenerate and renew the fuel instead of consuming fossil fuel.

The implementation of green practices in transportation gives cost reduction benefits for the movement of shipments, efficient vehicle allocation and planning opportunities, and natural and human resource advantages. Moreover, it further reinforces the image of the products. Green transportation further gives customer retention advantage as customer's interest has been shifted toward green products; therefore, companies have an opportunity to implement environment-friendly transportation to grab mass market [48].

8. Drivers and barriers of green transportation

Among many barriers there are two features that are considered as the main problem, which include the renewing system for electrical energy and generating fuel for vehicle that produces less emission. The historical activity of road transportation and consumption of energy has been growing rapidly which has apparently increased the challenges for the adoption of green transportation [16].

Previous studies outlined several challenges in implementing green GSCM and green transportation. Some of these barriers include unwillingness to shift logistic operations to green management, fear of investing capital for adoption of GSCM, and threats of not getting the desired return after implementation [11]. Many logistic managers only provide the training of green practices but fail to carry out their practical implementations which consequently, reduces the environment-friendly performance. To overcome these challenges, **Table 1** shows the following measures.

	Connectivity access	**Change or shift**	**Enhancement**	**Supportive tools**
Measures	Sound green practices can reduce trade barriers	Public transportation, supply chain process, rail freight, fuel and energy consumption	Efficiency in fuel consumption, alternative strategies for fuel generation, cleaner fuel	Awareness, timely monitoring, develop institutions, training
Useful instruments	Changes in policies for green transportation	Action plans to encourage more organizations, awards, recognition, and expert guide	Road maps for growth, green fuel consumption, schemes of green freight labeling	Development in curricula for undergraduate future employees, awareness campaigns, knowledge centers
Benefits	Social and economic growth, customer retention	Sustainable environment, safe living standards	R&D policies, trade and economic growth, security of energy consumption, single market	ISO, certifications for CSR activities
Operators	Governmental organizations dealing with laws for safety and sustainability of environment	Urban development, corporation of technical authorities, local governmental bodies	Transport ministries, economic centers, civil societies, environmental security centers, ports, and trading sectors	Societies: academic, civil, local Transportation ministries

Table 1.
Drivers for green transportation.

9. The role of green energy in green supply chain management

In Europe it is observed that for the suitability of cargo transportation, communication channels play a pivotal role [10]. In logistic industries, governmental bodies and shipment service providers regulate the environmental management and shipment of units to the end users. Both of these parties work to ensure the safety for the friendly environment. The concept of green transportation is derived from generating the green fuel which is less harmful for the society. The term less harmful refers to the reduction and control over the emission of carbon gases and fuel consumption to enhance the credibility of goods transportation.

Green fuel generation is a basic element to attain the benchmark of green transportation. It is observed that biomass is the best alternative against fossil fuel. It allows combining all biomass chemicals to generate an eco-friendly fuel for vehicles, which will further help in promoting green transportation. According to Douvartzides et al. [49], green diesel has proved to be an excellent alternative for the combustion of energy with rousting properties of low emission.

10. Sustainability in green transportation in green supply chain management

To differentiate the performance of supply chain operations, it is necessary to consider factors that depend on the sustainability of overall cycle of logistics, i.e., green transportation [10]. The term sustainability of transportation refers to "a set of continuous, dynamic, and integrated guidelines and policies embraces economic, social and environmental goals that are fairly distributed and used effectively to meet the needs of transport community and generations have to be summarized only in the sustainability of the nature of transportation systems" [50].

The study conducted by Heiko and Darkow [51] claimed that transportation consumes about 20% of global energy. Since it has become a challenge for logistic industries to attain sustainability in green transportation, therefore they are more focused on getting insights into the requirements and needs of their customers and instruments to support their green practices [48]. To achieve sustainability in green logistics and transportation, it has become crucial to eliminate elements such as methods that affect the autonomy of vehicles.

Sustainability in transportation can be achieved by enhancing the quality of air by reducing the emission of gases from the road transport and implementing a limit to the emission of harmful gases for all the vehicles. The following are the measures that manufacturing industries can take in their logistic and green transportation to achieve sustainability:

1. Modify the transportation system to affordable, easy, and reliable mode, which could be easy to assess by all users.

2. Implement diverse medium such as bicycles, walking, and electric vehicles (EV) and recharging stations which is implemented by IKEA stores in many countries.

3. By using hybrid and alternative fuels, vehicles could be limit in emission of carbon, which is a key element of sustainability in green transport [52].

11. Current practices in green transportation implementations in green supply chain management

The demand for green transportation has been increasing rapidly in the global world. The purpose for initiating green transportation is the emission of CO_2 gas which has been growing intensely since 1990 and consequently risking the environment through freight transportation. It has increased with the percentage of 71% in 2016 and anticipated to increase 50% more till the year 2050 [16].

Recently international markets are focused on environmental safety and sustainability by eliminating gas emission rather than promoting the implementation and practices of clean green technologies and energies in transportation [10]. The United Nations has established an agency to protect the marine cargo and shipment known as the International Maritime Organization (IMO). The responsibilities and roles of IMO are to prevent the pollution of marine that is generated during the shipment of consignments, enhance the performance of shipment, and ensure the safety and security of international transportation. For the initiative of environmental safety, the IMO has designed four ways to limit and control the emission of polluted gases. These methods include energy efficiency design (EED), energy efficiency operational indicator (EEOI), ship energy efficiency management plan (SEEMP), and market-based measures (MBM). The role of EED is to measure the reduction of emission through technical tools, whereas EEOI and SEEMP both measure the operations that should be carried forward for the purpose of mitigating the greenhouse carbon. MBM has the responsibilities to operationally and technically measure the carbon markets such as the trading system emission [53].

12. Recent trends of green transportation in green supply chain management

The demands of public for the import goods are changing dramatically. This change in demands has also shifted many manufacturing and transport industries by adopting the green technologies and seeking new ways to make their operations flexible for environmental concerns. It has been observed that reduction in fuel consumption from the large ships can significantly limit the emission of carbon.

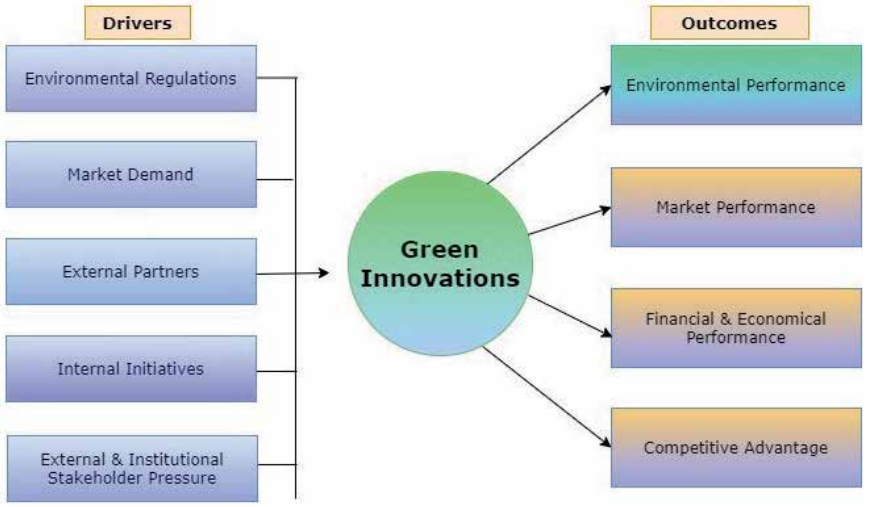

Figure 3.
Drivers and Outcomes of Green Innovations. Source: Qudrat-Ullah [54].

Figure 3 provides a brief overview regarding the drivers and outcomes of green innovations. Furthermore, there are various ways to reduce the emission of carbon, which will be discussed below.

12.1 Slow steaming

It is defined as a practice where the sails are moved slower than their designed speed. According to a study of the IMO, the emission reduction of carbon was decreased by 796 million tons in 2012 from 885 million in year 2007 worldwide. The main factor behind this reduction was the slow steaming of the cargo ships and vessels that consumes relatively low fuel which emits less carbon [55]. Different factors encouraged the adoption of slow steaming. These factors did not only focus on providing considerations toward the sustainability requirements to maintain the global supply chains but were further centered toward other important factors which include:

a. Management of the global financial crisis which ultimately caused the downturn in the global economy.

b. Another considering factor includes the high fuel costs.

c. Increasing operating cost rates.

d. Falling freight rates.

These factors resulted in the reduction of speed and minimal consumption of fuel which, in broader perspective, results in the reduced emission of greenhouse gases.

12.2 Voyage optimization

The massive use of voyage optimizer generated the need for the development of freight model. This process enhances the management and efficiencies of the ships by modifying the routes and speed of the shipping which consequently bring the ecological and economic advantages.

12.3 Efficiency in port operations

It is asserted that for mitigating the risking impacts of port management, manufacturing and transportation industries need to switch their decision to environmental sustainability from financial sustainability. It is also observed that by transportation layout, change is necessary to reduce the carbon emission such as shifting to rail tracks from road transport.

13. Future directions of green transportation in green supply chain management

Suppliers, customers, and their need of the transportation possess an important role to broaden the concept of logistics. Many companies have integrated advancement in vehicle technologies to enhance the performance of the environment and transportation of freight as well as transportation services for public. Data envelopment analysis (DEA) is observed to be an efficient method to evaluate the performance and efficiency of green practices in logistics and transportation.

The DEA model helps to measure the efficiency of the green supply chain process in terms of cost, human resource, energy, output, and carbon emission. The logistic managers need to enhance their transport system and let it lose free that will boost company growth, and vice versa it will positively influence economic growth which will result in building a healthy and strong nation [30].

Green transportation in supply chain management is further connected to the development of sustainability and green economy which can be achieved by the implementation of sustainability principles in countries. The importance of sustainability in green economy can be understood under two folds. The first includes the role of carrier in providing huge environmental impacts such as greenhouse gas emissions, while the later includes the reduction of air and noise pollutants along with the fuel management for sustainable development. It is important to emphasize that the use of resources is more important than the resources in developing a strong infrastructure.

Another important consideration must be provided to the transport infrastructure of the city which is defined through the scale of access to public transportation and the quality of roads, followed by the access point within them. These access points lead to a metropolitan area while providing important considerations toward travel time, distance, and the overall travel cost. It is noteworthy that a smooth infrastructure in transportation networks results in providing a direct effect on the scale of various local markets [50].

Other important concerns regarding the development of green transportation must be provided to the issues associated with the remaining available resources of fossils that are highly usable and can be infused in the internal combustion engines (ICE). In addition to that, the preservation and sustainable use of available reserves of lithium and other metals is highly favorable for the rapid development of green transportation since these metals are used in batteries and motors of electrical vehicles.

This transition of polluted cars to EV is characterized through the convergence of energy and mobility which may ultimately bring significant benefits to green transportation. Presently, the implementation of the propelled electric vehicles can be held through two different technologies that include fuel cells and batteries. These technologies are effective in developing the future by working on the strengths initiated through specific segments.

Battery electric vehicle (BEV) serves as the optimal solution for the short city routes, whereas fuel cell vehicle (FCV) is favorable for longer routes of huge tracks and other passenger busses. Both FCV and BEV technologies are favorable and are considered as "green" for environment since they lack the ability to produce greenhouse-related gases and other air pollutants. This is due to the fact that these technologies shift the challenge of green transportation centered for millions of individual vehicles to a central energy production place. Currently, BEV is one of the leading technologies; however, the new government policies are providing a significant interest toward the increased investments in research and development (R&D) that are expected to deliver better performance and maximum efficiency of FCV followed by their efficient recharging and better infrastructure. In the light of this, to develop green transportation for green supply chain management, it is important to develop future synergy of the abovementioned technologies which may ultimately result in best features.

Another important driver for green innovation is to provide important care to supplier's role. For the achievement of the green supply chain and green environmental targets, the right selection of supplier plays a critical role for the successful adoption and implementation of the green innovation in business firms. For the right selection of supply manager, it is important to provide firm consideration toward factors such as green purchasing abilities, green competencies, environmental management initiatives, environmental investments, and environmental

regulatory compliance followed by the end economic benefits. This is due to the fact that in supply chain management, supply-related factors play a critical role in managing the environmental processes effectively. It further supports the intervention of innovation and creativity in business process. The study of Burki [56] emphasized the selection of effective suppliers, as they play a key role in increasing firm's ability to adopt and accomplish the environmentally friendly work processes that are useful for environmental management and green innovation system.

It is further essential to prioritize the activities in the process related to green logistics and green transportation by elevating the transportation sectors. This modification will reduce the waiting time in supply chain cycle of product and simultaneously improve the efficiency of energy consumption. There are some important future implications in green supply chain management which is subsequently associated with green transportation:

1. Practices of reusing and recycling the material throughout the production cycle which will reduce the consumption of energy to minimum.

2. Seeking for the ways to minimize the wastage by utilizing minimum materials for the packaging.

3. Designing the product design that is easy to deliver. This could include the example of IKEA, who designed their packaging that require less space in shipment.

4. Purchasing the raw material that has absolute minimum or no negative impact on the environment.

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References

[1] Dwivedi A, editor. Innovative Solutions for Implementing Global Supply Chains in Emerging Markets. United States: IGI Global; 2016. pp. 243-255. DOI: 10.4018/978-1-4666-9795-9

[2] Sarkis J, Dou Y. Green Supply Chain Management: A Concise Introduction. Routledge. New York: Taylor and Francis; 2017. DOI: 10.4324/9781315233000

[3] Shan W, Wang J. Mapping the landscape and evolutions of green supply chain management. Sustainability. 2018;**10**(3):1-23. DOI: 10.3390/su10030597

[4] Sharma VK, Chandna P, Bhardwaj A. Green supply chain management related performance indicators in agro industry: A review. Journal of Cleaner Production. 2017;**141**:1194-1208

[5] Weeratunge RD, Herath R. The dimensions of green supply chain management practices. In: Proceedings of the 3rd World Conference on Supply Chain Management. Vol. 2. 2017. pp. 123-132. DOI: 10.17501/wcosm.2017.2111

[6] Silva GM, Gomes PJ, Sarkis J. The role of innovation in the implementation of green supply chain management practices. Business Strategy and the Environment. 2019;**28**(5):1-14. DOI: 10.1002/bse.2283

[7] Intravaia D, Viana FLE. The evolution of green supply chain management implementation drivers. In: 5th World Conference on Production and Operations Management Proceedings. 2016. pp. 1-11

[8] Bajaj PS, Bansod SV, Paul ID. A review on the green supply chain management (GSCM) practices, implementation and study of different framework to get the area of research in GSCM. In: Techno-Societal 2016, International Conference on Advanced Technologies for Societal Applications. Cham: Springer; 2016. pp. 193-199

[9] Dubey R, Gunasekaran A, Papadopoulos T. Green supply chain management: Theoretical framework and further research directions. Benchmarking: An International Journal. 2017;**2**(1):184-218

[10] Lu M, Xie R, Chen P, Zou Y, Tang J. Green transportation and logistics performance: An improved composite index. Sustainability. 2019;**11**(10):1-17. DOI: 10.3390/su11102976

[11] Gandhi M, Vasudevan H. Green supply chain management practices and its impact on business performance. In: Proceedings of International Conference on Intelligent Manufacturing and Automation. Springer; 2019. pp. 601-611. DOI: 10.1007/978-981-13-2490-1_56

[12] Onurlubaş E. Knowledge levels of the consumers about eco-friendly products. The Journal of International Scientific Researches. 2017;**2**(7):10-18. DOI: 10.23834/isrjournal.343742

[13] Pourhejazy P, Kwon OK. A practical review of green supply chain management: Disciplines and best practices. Journal of International Logistics and Trade. 2016;**14**(2):156-164. DOI: 10.24006/jilt.2016.14.2.002

[14] Samajdar A. Green transportation—A step towards a clean environment. In: Envibrary, Your Virtual Library for the Environment. 2018. Envibrary.com Available from: https://envibrary.com/green-transportation/

[15] Sun J, Zhu Q. Organizational green supply chain management capability assessment: A hybrid group decision making model application. IEEE Engineering Management Review.

2018;**46**(1):117-127. DOI: 10.1109/emr.2018.2809907

[16] Teter J, Cazzola P, Gul T, Mulholland E, Le Feuvre P, Bennett S, et al. The Future of Trucks: Implications for Energy and the Environment. France: International Energy Agency; 2017. pp. 1-166. DOI: 10.1787/9789264279452-en

[17] Khan SAR. Introductory chapter: Introduction of green supply chain management. In: Green Practices and Strategies in Supply Chain Management. China: IntechOpen; 2019. pp. 1-11. DOI: 10.5772/intechopen.81088

[18] Environmental Protection Department. Green Procurement. The Government of the Hong Kong Special Administrative Region. Hong Kong; 2018. Available from: https://www.epd.gov.hk/epd/english/how_help/green_procure/green_procure.html

[19] Franchetti MJ, Elahi B, Ghose S. Green supply chain, logistics, and transportation. In: Green and Lean Management. Portugal: Springer; 2017. pp. 1-16

[20] Rostamzadeh R, Govindan K, Esmaeili A, Sabaghi M. Application of fuzzy VIKOR for evaluation of green supply chain management practices. Ecological Indicators. 2015;**49**:188-203

[21] Ren R, Hu W, Dong J, Sun B, Chen Y, Chen Z. A systematic literature review of green and sustainable logistics: Bibliometric analysis, research trend and knowledge taxonomy. International Journal of Environmental Research and Public Health. 2020;**17**(1):1-25. DOI: 10.3390/ijerph17010261

[22] Sutduean J, Joemsittiprasert W, Jermsittiparsert K. Supply chain management and organizational performance: Exploring green marketing as mediator. International Journal of Innovation, Creativity and Change. 2019;**5**(2):266-283

[23] Suhardi AR, Abdul R, Saudi MHM, Sinaga O. Supply chain management and total quality management in textile manufacturing companies, Bandung. Journal of Advanced Research in Dynamical and Control Systems. 2019;**11**(3):173-177

[24] Nguyen MH, Phan AC, Matsui Y. Contribution of quality management practices to sustainability performance of Vietnamese firms. Sustainability. 2018;**10**(2):1-31. DOI: 10.3390/su10020375

[25] Speranza MG. Trends in transportation and logistics. European Journal of Operational Research. 2018;**264**(3):1-20. DOI: 10.1016/j.ejor.2016.08.032

[26] Santha T. Multimodal Transportation and Supply Chain Management; 2015. pp. 91-116

[27] Mei J, Messiah EKA. The impact of transportation management system on supply chain management: The effectiveness of Chinese online shopping delivery—The "Kuaidi" system. European Centre for Research Training and Development. 2017;**5**(2):1-9

[28] Romanow P. Role of Transport Operators in the Supply Chain. Poland: Poznan School of Logistics Press; 2016. pp. 165-176

[29] Dettmer P. An optimisation model for intermodal transportation in humanitarian logistics: Development of a decision support tool for supply network design in east africa. [Masters Thesis]. Germany: Georg August Universitat Gottingen; 2017

[30] Agamez-Arias ADM, Moyano-Fuentes J. Intermodal transport in freight distribution: A literature

review. Transport Reviews. 2017;**37**(6):782-807

[31] Rodrigue JP. Developing the logistics sector: The role of public policy. New York: Hofstra University; 2018

[32] Forbes. How IKEA Builds Sustainable Innovation into its Business Model to Improve Lives. 2018. Forbes.com Available from: https://www.forbes.com/sites/sap/2018/05/29/how-ikea-builds-innovation-and-sustainability-into-its-business-model-to-improve-lives/#201c5f0577f1

[33] Waller M, Meixell MJ, Norbis M. A review of the transportation mode choice and carrier selection literature. The International Journal of Logistics Management. 2008;**19**(2):183-211

[34] Banker S. Pipelines: A Mode of Transportation that Gets No Respect. 2019. Forbes.com. Available from: https://www.forbes.com/sites/stevebanker/2019/07/01/pipelines-a-mode-of-transportation-that-gets-no-respect/#43d9c55278a2

[35] Lahoti N. Micromobility: The next wave of eco-friendly transportation. 2019. Mobisoft.com, Texas. Available from: https://mobisoftinfotech.com/resources/blog/future-of-micromobility/

[36] Rubiano LC, Jia W, Darido G. Innovation in the air: Using cable cars for urban transport. USA: World Bank Blogs.com. 2017. Available from: https://blogs.worldbank.org/transport/innovation-air-using-cable-cars-urban-transport

[37] Lawrence Livermore National Laboratory. Drones Deliver Green Transportation Option. United Kingdom: Techxplore; 2018. Available from: https://techxplore.com/news/2018-02-drones-green-option.html

[38] Stern NH. The Economics of Climate Change: The Stern Review. United Kingdom: Cambridge University Press; 2007

[39] Campos JK, Schoeder D. Sustainable distribution in the consumer goods supply chain. In: Proceedings of the Hamburg International Conference of Logistics-21. 2015. Available from: https://pdfs.semanticscholar.org/c92a/54b62a5870b7e3e924844ed02c1ffef90bdc.pdf

[40] Ho JC, Shalishali MK, Tseng T, Ang DS. Opportunities in green supply chain management. The Coastal Business Journal. 2009;**8**(1):18-31

[41] Jiange TAO. Researches on Establishment Model of Green Logistics System. China: Zhongyuan University of Technology. 2008. pp. 533-537. Available from: http://www.seidatacollection.com/upload/product/201002/12652765911ylezfx9.pdf

[42] Ninlawan C, Seksan P, Tossapol K, Pilada W. The implementation of green supply chain management practices in electronics industry. In: World Congress on Engineering 2012; 4-6 July 2012; Vol. 2182. London, UK: International Association of Engineers; 2010. pp. 1563-1568

[43] Zhang Y, Liu J. The establishment of green logistics system model. In: Proceedings of 2009 International Conference on Management Science and Engineering. 2009. pp. 892-897

[44] Cosimato S, Troisi O. Green supply chain management: Practices and tools for logistics competitiveness and sustainability. The DHL case study. The TQM Journal. 2015;**27**(2):256-276

[45] Sturman C. IKEA Building Sustainable Success. Construction Global; 2017. Available from: https://www.constructionglobal.com/sustainability/ikea-building-sustainable-success

[46] PHYS ORG. Renting Flat-Pack Furniture? Ikea's Push to Go Green. United Kingdom: Phys.org.com. 2019. Available from: https://phys.org/news/2019-04-renting-flat-pack-furniture-ikea-green.html

[47] Scania, Sustainable Transport Ikea Encourages Alternative Fuels. Scania.com. Available from: https://www.scania.com/global/en/home/experience-scania/features/ikea-we-encourage-our-carriers-to-use-alternative-fuels.html

[48] Navarro P, Cronemyr P, Huge-Brodin M. Greening logistics by introducing process management–A viable tool for freight transport companies going green. Supply Chain Forum: An International Journal. 2018;**19**(3):204-218

[49] Douvartzides SL, Charisiou ND, Papageridis KN, Goula MA. Green diesel: Biomass feedstocks, production technologies, catalytic research, fuel properties and performance in compression ignition internal combustion engines. Energies. 2019;**12**(5):809

[50] Ali Mohammadi Chermahini AH, Mokhtari Sharafabad A. Examination of sustainable transportation in approach to sustainability. International Journal of Urban Management and Energy Sustainability. 2019;**2**(1):54-59

[51] Heiko A, Darkow IL. Energy-constrained and low-carbon scenarios for the transportation and logistics industry. The International Journal of Logistics Management. 2016;**27**(1):142-166. DOI: 10.1108/ijlm-12-2013-0150

[52] Willoughby S. Sustainable Customer Transportation an Opportunities Guide for Retailers and Shopping Centers. World Wildlife Fund. 2011. Available from: http://assets.panda.org/downloads/wwfikea_stop_1.pdf

[53] Prill K, Behrendt C, Szczepanek M, Michalska-Pożoga I. A new method of determining energy efficiency operational indicator for specialized ships. Energies. 2020;**13**(5):1082

[54] Qudrat-Ullah H. Innovative solutions for sustainable supply chains: An introduction. In: Innovative Solutions for Sustainable Supply Chains. Cham: Springer; 2018. pp. 3-13

[55] Psaraftis HN. Speed optimization vs speed reduction: The choice between speed limits and a bunker levy. Sustainability. 2019;**11**(8):2249

[56] Burki U. Green supply chain management, green innovations, and green practices. In: Innovative Solutions for Sustainable Supply Chains. Cham: Springer; 2018. pp. 81-109

Chapter 4

Green Supply Chain in Solid Waste Management: Case Study of EcoCare H2H Waste Collection, Goaso, Ghana

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Abstract

Today, Green supply chain management (GSCM) has become a multidisciplinary concept by constructing environmental management practices in the context of various supply chains including waste management services. Environmental issues have become an important integration into the supply chain management, so that each step from organization's materials management and transportation functions to the end customer can be structured to include environmental awareness. The authors analyze the levels of application of GSCM in waste management value chain of Ghana and use our house-to-house waste collection model as case. Review of the social, environmental and economic impacts made by waste EcoCare and other solid waste management companies that incorporate circularity – at least a recovery and recycling channel at some point – into their service shows are setting a pace for understanding, adoption and replication of green supply chain management (GSCM) into waste management in the country. The authors recommend that private-public-partnerships for waste management in Goaso and other cities would be greener if they replicated the circular economy model implemented by EcoCare Waste Initiative and its H2H Waste Collection model.

Keywords: supply chain, environment, circular economy, sustainability, solid wastes, EcoCare, TBL, sanitation

1. Introduction

In recent years, the value that society places on reducing greenhouse gas (GHG) emissions and better stewardship of soil, water and wildlife is leading to consumer demand for climate-friendly production methods and supply chain. In addition there has become a greater level of the world's appreciation of the impact of climate change and environmental sustainability. There is also society's general consciousness of personal and public health in relation to products that they use. And then there is an increase awareness of the Sustainable Development Goals (SDGs) especially the SDG12 – sustainable consumption and production. Day in and out people are becoming more concern of environmental issues, consumers thus ask a lot of questions these days about the authenticity of products that they buy.

And we question how green producers manufacturing processes are, how big their carbon footprints are and how they recycle [1]. Various supply activities can have a significant threat to the environment. These threats vary but in terms of carbon monoxide emissions, discarded packaging materials, scrapped toxic materials, traffic congestion and other forms of industrial pollution [2, 3].

This means that we are heading towards a near future where, people are becoming so conscious of their health and the ecology that, if your production or ecological service does not have anything to do with protection of the earth's resource, along its supply chain, you will not survive on both international and local markets. Undoubtedly, across all sectors of the economy, we see that companies are being influence to reformulate their environmental and supply chain models due to increases in environmental problems caused by products. Therefore, the requirement to extend companies' environmental activities to include the whole supply chain has been instrumental in the concept of green supply chain management (GSCM) [4]. It is therefore, reasonable to say that the requirement to extend companies' environmental activities to include the whole supply chain has been driving force of the development of the GSCM concept.

Green supply chain management is basically the integration of environmental thinking into various supply chain management (SCM) models. In the broader sense, GSCM can be considered an environmental innovation [2]. This is because, it's ultimate goal is to eliminate wastages including hazardous chemical, emissions, energy and solid waste along supply chain such as product design, material resourcing and selection, manufacturing process, delivery of final product and end-of-life management of the product [5, 6]. Also, because GSCM has become a multidisciplinary concept by constructing environmental management practices in the context of various supply chains [7], whether they directly provided environmental services or not. And finally, because GSCM plays a vital role in influencing the total environment impact of any firm involved in supply chain activities and thus contributing to sustainability performance enhancement [2]. Therefore, with the environmental issues becoming an integral part of the supply chain management concept, we see the context being extended so that each step from organization's materials management and transportation functions to the end customer can be structured to include environmental awareness [8].

It is against this backdrop that green supply chain becomes very important when designing environmental impact initiatives especially within environment organization such as waste management companies, or any social enterprise that works at the national, regional or community level to impact the triple bottom line from a green economy context. And this disposition spurs the authors of this chapter to do a review of literature in relation to the theme while reflecting on their work on waste, at their organizational level, to establish or reestablish the gains in waste value chains to inform policy makers to rethink the current waste management practices to accelerate the socioeconomic development of the country.

This chapter therefore, analyses the waste management services as key green initiatives in Ghana; siting the case of how EcoCare Waste Initiative an environmental startup in Goaso, Ghana, achieves green supply chain in its attempt to offer community waste collection service, the lessons that could be drawn.

2. Problems associated with unhealthy environments

It is noted that poor water, sanitation and hygiene, and indoor air pollution from burning wood for cooking and heating were as well as unconventional burning of wastes have been the cause of pneumonia and other common environmental related disease over and over again. In order to prevent these diseases, the environment

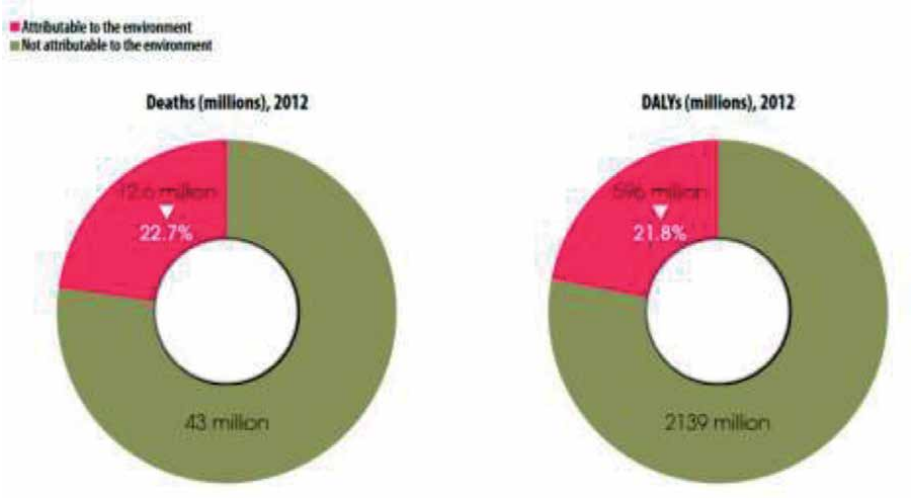

Figure 1.
Imagery illustration of the global deaths attributed to environmental factors (adopted from [10]).

needed to change [9]. The World Health Organization (WHO) estimates that, 24% of all global deaths – roughly 13.7 million deaths a year – are linked to environment risks such as air, water and soil pollution, chemical exposures, climate change and ultraviolet radiation. Beyond pneumonia and diarrheal diseases, these risks may contribute to more than 100 diseases and injuries [9, 10]. In sub-Saharan African region the 2.5 million deaths a year are attributable to environmental risks. Generally, the fraction of the global burden of disease due to the environment is 22% if we are accounting for both death and disability. And in children under 5 years especially, up to 26% of all deaths could be prevented, if environmental risks were removed [10]. These facts, show us the importance of ensuring that whatever product or service that impacts the environment is sustainable to give us healthy environments which will help prevent the greatest percentage if not all environmental related diseases.

Figure 1 below, adopted from [10] gives a nice patristic illustration of (i) the ratio of deaths attributable to environment to deaths by other facts, and (ii) ration of disability-adjusted life year (DALY) attributable to environment to DALY non-attributable to environment; globally in 2012.

3. Challenges with solid waste management

3.1 Problems with solid waste in developing countries

In the developing world, the private sector and various actors have been keenly involved in solid waste management over the past decades, yet there are still problems with solid waste delivery services [11]. The problems with solid waste in most urban cities of some countries have really become burdensome despite efforts being made by city authorities and governments. The problems of solid waste common in developing countries include the following but not limited to:

- inadequate service coverage,
- irregular waste collection,
- waste spill over from bins and storage containers, and

- lax attitude of people towards indiscriminate disposal at unauthorized places
- waste littering on streets and in gutters/drains
- indiscriminate burning of waste and
- pressure on dump sites (locally created landfills).

These solid waste problems are what consequently lead to environmental health problems, such as discussed in the previous section above. And not only do they impact environmental health, they also lead to esthetic nuisance, and environmental pollution in general [12, 13].

3.2 Challenges in solid waste value chains

One major challenge in handling solid waste problems is that these problems impact on each other and on the environment in a circular manner – which makes it difficult to only tackle only a single aspect of the solid waste value chain. For example, in Ghana, due to inadequate service coverage in many cities, rural settlements and slums, insufficient service coverage; the public dump uncollected solid waste into drains, rivers and surrounding areas, or it is locally burnt or buried. These practices lead to considerable environmental pollution and degradation, and pose serious health risk to the population. These problems impair, in the long run, not only the quality of life of the urban poorer communities but also affect the welfare of the entire urban population. These complexities are what make cities still faced with urban environmental health issues related to solid waste management [14].

On the other hand the main causes of these waste problems in developing parts are not feasible to tackle in isolation because they are enormous, and complex interconnected social, environmental and economic factors. First, rapid urbanization poses a big problem to urban solid waste management. The rapid and unregulated urban growth and development in urban areas lead to a situation where solid waste services infrastructure lag behind the growth in population, or simply overpowers government strengths to fund municipal solid waste management.

Second, low cost of solid waste recovery as well as limited funds from central government is another constraint to solving the challenges in the waste management value chaing in developing economies. Local authorities have difficulties in keeping pace with solid waste facilities development and in meeting the growing demand for solid waste services due to financial constraints.

Third, there is very low political will and priority given to solid waste service, Meanwhile most governments acknowledge immediacy and seriousness of solid waste problems to their countries. The lack of priority, political will, and public sector commitment limit rapid and sustainable improvements in the solid waste sector in developing countries like Ghana.

Fourth, there is also the factor of the enforcement solid waste management. This contributes to the lax attitude of the people towards indiscriminate disposal at unauthorized places, waste littering, and burning in open space. The enforcement of regulation by government officials appears to be weak and this may be due to lack of capacity, lack of resources and political will, and problems with the institutional set-up.

Finally, we have also noticed that there are problems with physical and human capacity for solid waste collection and technology operations in some countries. The human capacity of the public and private sector organizations may not be adequate and most of the few waste collection businesses that step in to contribute are usually not designed to be green, scalable and sustainable enough [14].

4. How green can waste collection be?

The root causes of solid waste problems have causal relationships with the various environmental and socio-economic factors that are already impacting the lives of populations living in these cities that are the most affected by the solid waste management challenge. That is why for our solid waste collection services to be sustainable enough, it must integrate social, environmental and economic impact models. If a waste collection service provider is able to consider the impact of their services on the triple bottom line – that is addressing social, environmental and economic variables – then we can say that the service is sustainable. **Figure 2** illustrates the intersessions of the social, environmental and economic variables that affect populations which when address makes a service sustainable.

First of all, the service must have measurable impacts on the social variables faced by the affected people and communities – that is to cause social change and improvement. This means for a waste collection services to be green it must address some social variables that deals with the community, education (e.g. increased awareness about effects of waste etc.), equity (e.g. reduction in child labor, increase in girl child education etc.), health, well-being and quality of life of the people.

Secondly, a green service must bring economic benefits to the populations involved. This means, not only must the service make some profits for its sustainable cash flow (to remain in business), the service provider must also factor the economic dynamics of the users when pricing its services, and the activities in the service must create jobs and employment opportunities. Thus they must offer a service that is available and affordable to all classes of the population.

Finally a green waste collection service must integrate protection of the environment at the core of serving the people and the economy. It must have considerations for saving natural resources, water, air quality, energy conservation and land use across all of its supply chains. If all aspects of a solid waste collection service – from procurement of logistics, collection of wastes and transport to disposal, are able to respect protection of the environments, reduce pollution and carbon emission, then we can say that such a waste collection service is green – it respects green supply chain management (GSCM).

Figure 2.
The interconnection of the elements of the triple bottom line concept (adopted from [15]).

5. Greening the waste supply chains: national to local contexts

Within the waste management industry a generalized broader way of defining waste would be: wastes are materials that are not prime products for which the generator has no further use in terms of his or her own purposes of production, transformation, or consumption and of which he or she wants to dispose [16]. And from national to local contexts we identify that:

- the extraction of raw materials,
- processing of raw materials into intermediate and final products,
- the consumption of final products, and
- other human activities are ways through which waste may be generated [17].

In Ghana particularly it is estimated that an average city generates about four thousand (4000) tons waste daily. To this end, the rate of waste generation in Ghana stands at 0.47 kg/person/day, which translates into about 12,710 tons of waste per day averagely [5].

The conventional methods of dealing with these waste in Ghana have included throwing into open dumps, wetlands, landfills, and uncontrolled dumps or in some cases are incinerated in the open air. Due to our current conventional approaches to dealing with waste, it is difficult to get a significant quantity of waste generated to go into recycling, composting or reuse to tap the potential end use value of solid wastes. However, if waste is properly managed – from generation to disposal – there are enormous untapped potentials that could be fully exploited. And this also have a consequential potential of improving greatly the quality of life for Ghanaians through energy generation, employment generation, income acquisition, and resource for goods production among others.

Therefore, the municipal solid waste (MSW) collection model ran by the government and city authorities where waste is collected and simply dumped at landfills by only one government agent or contractor, could be remodeled to make it more green and sustainable. We can decentralize the entire municipal waste management value chain – using a zonation approach. Government in an effort to rid the respective metropolis of the mountain of filths, these metropolises contract private waste management companies in a joint venture termed public-private partnerships (PPP) which over the years have witnessed a considerable increase particularly as witnessed in the Accra Metropolitan Assembly, to assist in the collection and disposal of MSW at landfill sites [16, 17]. This PPP for waste management could be replicated at local levels in peri-urban centers where we are witnessing an exponential growth of startups and youth organizations committed to social entrepreneurship [18–20].

When the waste management value chain is decentralized, what it also means is that we will have many actors – even SMEs and startups – on the various points of the waste value chain. Some will specialize on the collection to ensure that communities achieve 100 percentage recovery of waste from homes and the public. Which will also make waste collection service relatively affordable for every household to subscribe. More people subscribed to waste collection means little or no more indiscriminate disposal of waste at unauthorized places like drains, bushes and water bodies; and no burying or burning of wastes by households. Secondly, at local (zonal) levels, waste management companies could partner, together with government initiative, and build one major community owned state-of-the-art landfill

Figure 3.
Conceptual framework for green waste supply chains (from EcoCare pitch deck [23]).

system or incinerator. This will ensure that waste disposal in each community is not scattered to claim more arable lands that could be used for farming. Finally, while some waste service providers focus on collection and disposal, some others could only invest in treatment and recycling. The waste collected by company A from the same city could be sold to company B as raw material to be converted into various end-user resources like upcycling plastic wastes into bricks, tiles and ceramics or processing to produce energy like combustion chambers, gasification systems, liquefaction etc. [16, 21, 22].

Here, the authors propose a conceptual framework for turning wastes back into production chains in a circular economy manner – to make national and local wastes supply chains green. From the triple bottom line modeling, we considered EcoCare activities that result in economic gains, those that impact the environment and those that lead to social change. For a given community as an entity if a waste initiative is able to link all of its solutions to economic and environment holistically, that service will indirectly take care of its social impact variables (**Figure 3**).

6. Factors affecting waste management supply chains in Ghana

6.1 Actors and elements of solid waste management (SWM)

Solid Waste Management (SWM) could be defined as managing the processes involved in solid waste collection, treatment and disposal of waste generated in households, commercial and business establishments, institutions, and non-hazardous industrial process wastes. Solid waste collection has evolved over the years from collection of unsegregated waste and disposal on dumping grounds to collection of source separated waste streams through formal and informal service providers. The management of the processes involved which was traditionally public has now become public-private-community provision and partnerships arrangements [24].

The direct activities in solid waste management could be grouped into six functional elements basically:

1. waste generation and characterization,

2. on-site storage and handling,

3. collection,

4. transfer and transport,

5. separation processing, treatment and resource recovery, and

6. final disposal.

These functional elements require planning and management in order to achieve high quality of service. Unfortunately, however, the waste management value chain has not contributed to greening cities because most cities' agencies responsible for SWM often pay too little attention to integrated management approaches based on adequate information systems, management approaches, methods, and techniques. The activities of service provision may be concentrated in one organization or fragmented over multiple organizations.

As mentioned in Section 5 above, if solid waste management in cities is decentralized whereby various actors of waste management initiatives (private and public) were contracted to work on different activities of the waste value chains, it would be easy for cities to achieve green waste management supply chains. It is noted by [11] that these activities of the waste supply chain could best be regrouped into four fragmented stages, and it is best if different actors worked on different fragments in the process of making solid waste management green. A diagrammatic representation of the four fragmented process of waste management is shown by **Figure 4** below.

From **Figure 4**, we discover that at least 4 groups of elements and 4 groups of actors run through 4 stages of the waste management supply chain. Again we can see that a waste management supply chain can take a linear pathway (as is being done in most cities) and a circular pathway (which has only been promoted recently to be the most eco-friendly and green approach).

The linear waste management supply chain will take a path in which waste moves straight away from stage 1 (primary storage points) through stage 2 (collection and transport) to stage 4 (final disposal). In some typical rural communities in Ghana, the linear model could even involve just stage 1 (waste generators store long piles of waste in their houses for a long time) and then move it straight away to stage 4 (a local community dump site, call *"borla so"* in local dialect). This means that in the linear model, most actors may be left out. In the Stage 1–4 linear approach for example, you notice that households, institutions etc. who generate their waste at stage 1, store the waste, and then later send it to dump

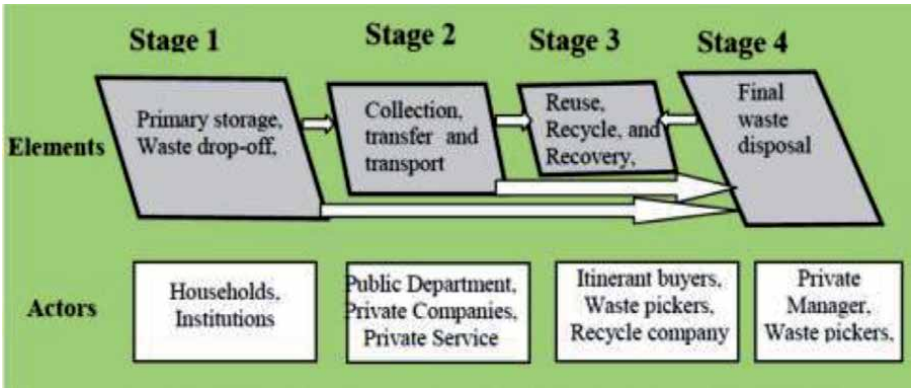

Figure 4.
Elements and actors in the solid waste management supply chain (adopted from [11]).

site by themselves – cutting off public and private waste collectors in stage 2, and even recyclers in stage 3.

On the other hand, the circular waste management supply chain is one that progress from Stage 1 through 2 and 3 to 4, then back to 3. What happens here is that, after the waste reaches the final stage they are not disposed completely into permanent landfills, but all or some percentage of the waste is recovered back for reuse, recycling and other purposes of getting the waste material back into a production cycle again. These waste recovered could be repurpose into other end user goods and products through various means of treatment and processing – such as organic compositing, plastic recycling and upcycling, plastic extrusion, reuse etc. With this circular model of solid waste management, all the actors across the 4 stages on the waste supply chain get some work to do, and contribute to making the city's waste management green and sustainable.

Table 1 gives an idea of how different types of solid waste could be repurposed in the circular economy waste management model.

Types of solid waste	Typical sources	Potential products	Methods (processes)
Agro waste (organic)	Rice, wheat, straw and husk, cotton stalk, saw mill waste, vegetable residues, nut, shells etc.	Organic soils and fertilizer, particle boards, insulation boards, wall panels, printing paper, roofing sheet, fuel, bricks, acid proof, polymer composite, cement board	Compositing, recycling, combustion, incineration, gasification
Industrial waste (inorganic)	Coal combustion residues, steel slag, bauxite red mud, construction debris	Cement, bricks, blocks, tiles, paint, concrete, ceramic products, wood substitute product	Combustion, liquefaction
Mining waste (mineral)	Coal washer waste, mining waste, tailing from iron, copper, zinc, gold and aluminum industries	Bricks, tiles, lightweight aggregate, fuel etc.	Combustion, liquefaction, biochemical esterification
Non-hazardous and other process waste	Waste gypsum, lime sludge, drains sludge, limestone waste, marble processing residues, broken glass and ceramics, kiln/oven dust (waste)	Cement clinker, super sulphate cement, hydraulic binder, blocks, cement, fibrous gypsum boards, gypsum plaster	Liquefaction, purification decontamination, recycling
Hazardous waste	Metallurgical residues, galvanizing waste, tannery waste	Cement, bricks, ceramic tiles and boards	Recycling, upcycling
Plastic waste* (various class of recyclable plastics)	Packaging, used plastic containers, oceans,	Reinforced fiber plastic, pellets, plastic beams, plastic artifacts, plastic jerseys, cement, plastic tiles and blocks, fuel, etc.	Recycling, upcycling, reuse, biochemical extraction

**We could not separate recycle and non-recyclable plastics as it is done commonly, so take these to be only plastics that could directly be recycled/or repurposed easily.*
[Source: authors' construct based on synthesis of various prototypes and recycled products in literature].

Table 1.
Types of waste and their repurpose potential in a circular waste supply chain.

6.2 Modes of solid waste collection services

According to 11 we can identify four modes of solid waste collection service[1] depending on the income levels of the people, housing types and the level of service required. They include:

a. *Communal[2] collection mode is rendered in low income areas. The householders discharge their waste into communal storage containers at transfer stations or designated locations and collection vehicles pick up the containers full of waste at frequent intervals.*

b. *Block collection mode is used where there are large apartment residential buildings. For this service, collection vehicle travels along a predetermined route at specific intervals (every 2–3 days) and stops at selected locations. The householders bring their waste bins upon hearing a bell sound and hand them to the crew who empties the bins and gives them back to the householders [11].*

c. *Kerbside collection mode is rendered in middle and high income areas. The collection crew collects bins and bags of waste which are deposited at the kerbside on fixed days (e.g. 2 specific days in a week) when collection takes place. The householders leave their bins at the kerbside and collect them later in the day [11].*

d. *Door-to-door or house-to-house[3] collection mode is rendered in middle and high income areas. The collection crew enters each premise, takes out the bin and sends it back after emptying the waste into collection vehicles. No bins are left out-side household premises*.

The residents served by the kerbside and house-to-house collection use standard bins to store waste. And this is what is practiced in the EcoCare H2H Waste Collection model.

7. The case of EcoCare waste initiative

7.1 The EcoCare story

A brief capture of the story of the EcoCare team and initiative could help paint a picture of how an environmental company could be born out of a passion to protect lives by cleaning and greening our environments. We capture this from an unpublished executive document of the EcoCare Waste Initiative [25]:

> *Jackson Nyarko the visionary of EcoCare had a friend who was part of the victims that lost their lives to the June 3, 2015 flood disaster in Accra, Ghana. One of the major cause of this disaster was later linked to a major drain that was choked by*

[1] Take *Collection service* in general as the collection of solid waste from households in the municipality or from communal storage point.

[2] *Communal collection*: A system for solid waste collection in which individuals bring their municipal solid waste directly to a central point, from where it is collected.

[3] *House-to-house collection*- Method of collecting domestic solid waste in which the house-holder is responsible for putting the waste (in a container) outside his property at the curb- or roadside at specified times for collection. The container should generally be kept within the property (definitions are adopted from [11]).

filth (plastic wastes especially) due to indiscriminate waste disposal. A year later, 2016, Jackson had the opportunity to participate in an Eco-enterprises development incubator. He was touched by his lost due to the indiscriminate problem to build a concept around Waste Management. In search of his first team members, Jackson first brought on board his Friend, Frank Yeboah, who also related to the loss of lives in that June 3rd disaster. So the 2 united their passion, loss and expertise to design EcoCare Waste Initiative. With the mission to challenge Ghanaians wasteful paradigm and throwaway culture. Then from there, their need to fill up the expertise gap brought in Felix Ankamah Yeboah (an environmental engineer), then later Isaac Sarfo Larbi, Maxwell Osei-Bonsu and the late Acheamponmaa Duffour.

7.2 The EcoCare business model

EcoCare Waste Initiative was set up with the sustainable development goal (SDG) 12 in mind first, then later partnerships (SDG 17) with other actors to integrate other goals – SDG 6 and 13 started running through the model. **Figure 5** below shows a non-updated business model of EcoCare developed by the co-founders which is used in modeling all the services and programs initiated by EcoCare since 2017.

7.3 Milestones towards a greening cities of Ahafo

Since the conception in 2016, the EcoCare team has been challenged by the daunting vision *"to become a world class environmental company solving global sustainability and ecological problems and inspiring African excellence."* And driven by the mission *"develop innovative technologies for managing wastes and protecting environments for people and communities,"* EcoCare has moved through 3 growth stages:

Through 2017–2018: EcoCare first focused on social campaigns against plastics pollution and indiscriminate waste disposal – mainly on social media (virtual) and talk shows in and around Goaso. At this point it was quite difficult to identify on which of the four stages (illustrated in **Figure 4**) that the EcoCare was acting. But it served as a foundation process.

Through 2019: EcoCare added EcoEvents Cleanup to its business model – where we did waste Collection and segregation at source (people's events like wedding receptions and funerals) - for revenue generation. Now it becomes clear to identify EcoCare as an actor at the Stage 2 and 4 – in a linear model of waste management.

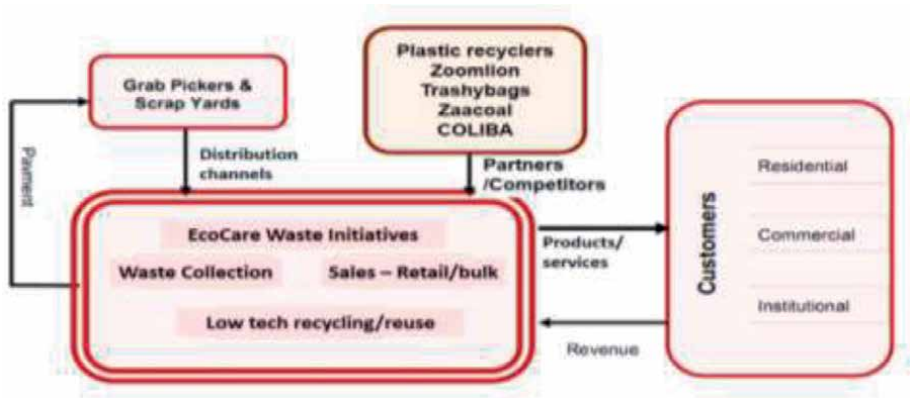

Figure 5.
Business model of EcoCare waste initiative (from EcoCare pitch deck for TEDxAccra, 2017).

- In May 2020, we rolled out the House to House Waste Collection Service (called H2H Waste Collection) in 4 "elite communities" in Goaso. This business model though currently on a small scale, has elements of primary storage (with segregation at source), collection, and recovery of recyclables before disposal at authorized landfill sites. Now you can see EcoCare acting across the 4 major stages of green waste supply green chain – in a circular mode. The next sub-section (7.3) describes some details of how the H2H Waste Collection makes EcoCare contribute to greening the waste management supply chain of Goaso.

7.4 The EcoCare H2H waste collection model

The EcoCare House to House Waste Collection was designed to achieve six (6) goals, but which will cut across the social, economic and environment triple bottom line and have a tremendous impact in setting a new pace for green waste management supply chain models in Goaso. The six goals are:

1. support municipal waste collection to reach all neighborhoods in Goaso – *Social*

2. help every household to adopt the behavior of segregating their wastes – *Social*

3. ease families of monthly sanitation bills by cheap and easy payment plans – *Economic*

4. create direct and indirect jobs for waste supply chain in Goaso – *Economic*

5. ensure prompt collection and odor free neighborhoods – *Environment*

6. make Goaso the cleanest district capital in Ghana – *Environment*

So moving from the conventional linear approach to solid waste management, the EcoCare H2H Waste Collection has introduced a circular model by:

a. supplying waste bins for storage of waste in households,

b. supplying recycling bags for segregation of recyclable wastes at the homes (source),

c. prompt collection of wastes on weekly basis,

d. recovering and storing recyclables waste (e.g. plastics, glass, paper etc.) at our warehouse,

e. transporting disposable waste to authorized community landfills and

f. Distributing recovered recyclable wastes to partner recycling companies.

Without capacity to recycle, EcoCare is currently creating a distribution model for connecting with plastic recycling companies within Ahafo who will receive our recovered wastes as raw materials for the recycling plants. This will ensure that even while we do not have the capacity to complete our circular model, by partnership with other actors in the sector we could still make a complete green waste supply chain.

8. Results and lessons learned from EcoCare and the green initiatives

Most cities in Ghana continue to spend on solid waste management whereas others in other parts of the world persistently generate clean energy, income and raw materials and social development through the solid waste value chains. The common practice of waste management in Ghana since independence, which has been the linear supply chain approach – where we just collect and dispose – has not been very much beneficial until the last decade.

In recent years, some actors in the waste management industry have made efforts to transform Ghana's sanitation services into a more sustainable development (circular economy) model – where different actors partner to work on different aspects of the waste value chain. By so doing, today, not only do we see collect and dump waste management services, but also there are being a crop of recycling initiatives coming in.

Initiative/ service	**Status**	**Impact*** **		
		Social	**Environmental**	**Economic**
EcoCare plastic free campaigns*	Active in 2017–2019; No current active challenge in 2020	Impacting and influencing climate action and responsible consumption and production in 70 members	Saved 21,900 L of water in 2018–2019 by our community of 70 environmental lovers through the challenge	Several indirect jobs and revenue created for partners and suppliers – e.g. *media* houses, graphic designers, web/app designers
EcoEvent cleanup service	Operated in 2019; Not operated yet in 2020	Influenced the way event organizers manage their waste in Goaso	Reduced amount of waste that ended up at dump site in Goaso during weekends; Expected to save up to 6516 tons of CO2-eq emission from waste burning by 2022	Created 11 direct jobs within, 2 outside; several indirect jobs
EcoCare DIY recycling training	Active 2018–2019	Influenced 600+ youth and students to consider waste as a resource for artifact creation	Prevented indiscriminate throwing of plastic wastes;	Provided skills for youth and women in plastic craft work
EcoCare H2H waste collection**	Rolled out in May 2020; Operated for about 10 weeks now	Served and impacted 16 households to choose paid waste collection service, learn to practice segregation of waste and control their waste generation	1800 kg of wastes collected and properly disposed in 8 weeks of active operation; 11.25 kg waste per household per week; Generation is fairly constant	Created 3 different direct jobs for transporters, collectors and recyclers; 1/3 of waste generated go into recycling for revenue creation etc.

** Plastic Free Campaign is global remote community (across 7 African countries) so impact are more global than local.*
*** Find highlights of impacts discussed in Sec 9 below, since H2H Collection is the main model discussed for this chapter.*
**** Some values are estimates from our unpublished Impact Assessment.*

Table 2.
Social, environmental and economic impacts of EcoCare's green initiatives.

There are large scale companies like Zoomlion, Surfisana, and CleanTeam etc. contributing to this new revolution to transform Ghana's linear waste management supply chain into a more circular sector. And interestingly, the efforts of environmental SMEs which are even at startup stages but are more passionate about circular economy, are inspiring green initiatives in Ghana, and EcoCare Waste Initiative is the number on of such inspirations for the Asunafo North Municipality and almost the entire Ahafo region of Ghana.

Since 2017, EcoCare has been into advocacy and contributed a voice to speaking out for a change in Ghanaians behavior towards indiscriminate disposal of waste, plastic pollution, environmental depletion and a call for circular economy in the environment industry. And EcoCare Waste Initiative was the first the startup to inspire the small scale local green waste supply chain model in Goaso, which few other startups and youth groups are to replicating today in the Asunafo North Municipality.

Table 2 below shows the four (4) main initiatives that had been rolled out by EcoCare since incorporation in 2017; and the impacts that these activities have made across the social, environmental and economic development variables of Goaso and other.

9. Summary and way forward

From a careful review of the results and lessons learned from EcoCare and other solid waste management companies that incorporate circularity into their services, we found that incorporation of a recovery and recycling channel at some point makes them contribute greatly to greening their environments. And such services are setting a pace for understanding, adoption and replication of green supply chain management (GSCM) into waste management in the country.

Waste generation among the user communities of EcoCare's H2H Waste Collection, has been fairly constant. Meaning users are influenced to keep their waste generate at a moderation (in check) since the bin provided them is not the usual larger bins that public services provide. Also, the weekly collection and pay per pickup plan of the H2H Collection service influence users to not exceed their thresholds between weekly pickups.

Customer feedback tells us that the people prefer this service to the conventional collect and dump model. Feedback also suggests that a flexible and affordable payment plan has a potential to motivate more households to subscribe to paid waste collection services, rather than resort to their indiscriminate disposal of wastes.

A green supply chain model like the H2H Waste Collection also makes users (the people) feel a part of contributing to keeping their cities clean and green. This could be true because customers generally accepted the responsibility for the environmental pollution in their neighborhoods caused by the dumping of wastes at unauthorized places or long term storage of piles of wastes in their backyards.

The H2H Waste Collection model is highly commended for the fact that it connects multiple actors in the waste service, and opens door for more jobs and economic activities to be created in the city if the public municipal solid waste department adopts this model too.

Over all, if successful, we are optimistic that these four (4) green initiatives provided by EcoCare Waste Initiative could create 1000+ decent direct employment activities and 1000 change agents for the global goals on sustainable consumption and production (SDG 12) by 2022 from recycling model alone.[4]

[4] Enayetullah and Sinha [26], TEDxDhaka estimates recycling 1ton of waste creates 2 new jobs for waste pickers etc.

The authors recommend that private-public-partnerships for waste management in Goaso and other cities would be greener if they replicated the circular economy model implemented by EcoCare Waste Initiative and its H2H Waste Collection model.

10. Conclusion

One key factor that affects green supply chain management (GSCM) is the integration of environmental value proposition. Environmental companies thus have little to do to achieve a green supply chain model, since their business models start with providing solutions to environmental problems, with consequential impacts on social and economic variables. EcoCare, a waste management startup in Goaso, Ghana, has proved that incorporating the triple bottom line, in municipal solid waste management – according to a circular economy model – is very possible, and that more cities have the potential to respecting the green supply chain management. Four main activities of EcoCare Waste Initiative – Plastic Free Campaigs, EcoEvent CleanUps Service, DIY Recycling Training and H2H Was Collection service – have been found to contribute to the greening the waste collection supply chain in Goaso, the capital of Asunafo North Municipality and the Ahafo region of Ghana. The House-to-house waste collection service (EcoCare H2H) ran by EcoCare is setting a pace for green supply chain management in Goaso.

Conflict of interest

The authors declare no conflict of interest.

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References

[1] Murray M. Introduction to the green supply chain: Starting to create a green supply chain can add to the bottom line [Internet]. 2019. Available from: https://www.thebalancesmb.com/introduction-to-the-green-supply-chain-2221084 [Accessed: January 21, 2019]

[2] Chin TA, Tat HH, Sulaiman Z. Green supply chain management, environmental collaboration and sustainability performance. Procedia CIRP. 2015;**26**:695-699. DOI: 10.1016/j.procir.2014.07.035

[3] Wisner JD, Tan K-C, Leong GK. Supply Chain Management: A Balanced Approach. 3rd ed. Canada: South-Western Cengage Learning; 2012

[4] Sezen B, Çankaya SY. Green supply chain management theory and practices. In: Akkucuk U, editor. Ethics and Sustainability in Global Supply Chain Management. IGI Global: United States of America; 2017. pp. 92-114. DOI: 10.4018/978-1-5225-2036-8.ch005

[5] Rao P. Greening of Suppliers/ In-bound Logistics In the South East Asian Context. In: Sarkis J, editor. Greening the Supply Chain. London: Springer; 2006. DOI: 10.1007/1-84628-299-3_11

[6] Srivastava SK. Green supply-chain management: A state-of-the-art literature review. International Journal of Management Reviews. 2007;**9**(1):53-80

[7] Eltayeb T, Zailani S, Ramayah T. Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes. Resources, Conservation and Recycling. 2011;**55**(5):495-506. DOI: 10.1016/j.resconrec.2010.09.003

[8] Simpson D, Power D. Use the supply relationship to develop lean and green suppliers. Supply Chain Management. 2005;**10**(1):60-68. DOI: 10.1108/13598540510578388

[9] Neira M. Environments should improve not harm our health [Internet]. 2016. Available from: https://www.who.int/mediacenter/ [Accessed: May 22, 2020]

[10] Prüss-Ustün A, Wolf J, Corvalán C, Bos R, Neira M. Preventing Disease through Healthy Environments: A Global Assessment of the Burden of Disease from Environmental Risks. Geneva: WHO Press; 2016. p. 147

[11] Oduro-Kwarteng S. Private sector involvement in urban solid waste collection [Thesis]. CRC Press/Balkema: Erasmus University, Rotterdam; 2011

[12] Zurbrugg C. Solid Waste Management in Developing Countries. Duebendorf, Switzerland: SANDEC/ EAWAG; 1999

[13] Oduro-Kwarteng S, Awuah E, Kotoka P. Solid Waste Man-Agement Practices in Kumasi, Ghana: Public Concerns and Attitude towards Disposal and Cost Recovery. The Netherlands: CRC Press/Balkema; 2006

[14] United Nations Habitat (UN-HABITAT). An Urbanizing World, Global Report on Human Settlements. New York: United Nations Centre for Human Settlements (HABITAT); 1996

[15] Dalibozhko A, Krakovetskaya I. Youth entrepreneurial projects for the sustainable development of global community: Evidence from Enactus program. SHS Web of Conferences. 2018;**57**:01009. DOI: 10.1051/shsconf/20185701009

[16] Abalo E.M, Peprah P, Nyonyo J, Ampomah-Sarpong R, and

Agyemang-Duah W. A Review of the triple gains of waste and the way forward for Ghana. Renewable Energy. Journal of Renewable Energy. 2018;**2018**. ID 9737683. DOI:10.1155/2018/9737683

[17] Shah R. Generation of waste by economic activities. In: Proceedings of United Nations Statistical Division, (UNSD Workshop on Waste Statistics). Geneva: UNECE/EUROSTAT/EE; 2012

[18] Ghana Statistical Service, Estimation of population in Ghana, Ghana, Accra, Ghana [Internet]. 2018. Available from: http://www.statsghana.gov.gh/ [Accessed: June 29, 2020]

[19] "Accra Metropolitan Assembly composite budget for the 2015 fiscal year. Republic of Ghana" [Internet]. 2015. Available from: http://www.mofep.gov.gh/sites/default/files/budget/2016/Composite/GR/AMA.pdf [Accessed: June 29, 2020]

[20] Accra Metropolitan Assembly (AMA), The Composite Budget for 2017-2019. Programme Based Budget Estimates. 2017 fiscal year. Republic of Ghana [Internet]. 2017. Available from: http://www.mofep.gov.gh/ [Accessed: June 29, 2020]

[21] Addaney M, Oppong RA. Critical issues of municipal solid waste Management in Ghana. Journal of Energy and Natural Resource Management. 2015;**2**(1):30-36

[22] Schubeler P, Wehrle K, Christen J. Conceptual Framework for Municipal Solid Waste Management in low-Income Countries. St. Gallen: Swiss Centre for Development Cooperation in Technology and Management; 1996

[23] "Kumasi Metropolitan Assembly composite budget for the 2016 fiscal year, Republic of Ghana" [Internet]. 2016. Available from: http://www.mofep.gov.gh/sites/default/files/budget/2016/Composite/AR/KMA.pdf [Accessed: June 29, 2020]

[24] Tchobanoglous G, Theisen H, Vigil S. Integrated Waste Management: Engineering Principles and Management Issues. New York: McGraw-Hill; 1993

[25] Nyarko J. Note to EcoCare Shareholders [Unpublished]; 2020. Source: http://www.ecocaregh.com

[26] Enayetullah I, Sinha M. Breaking Barriers. Dhaka: Oral Presentation at TEDxDhaka Conference; 2014

Chapter 5

Green Initiatives in Supply Chain Management Drives Enterprises' Competitiveness and Sustainability

Ken Mathu

Abstract

The advent of supply chain management (SCM) strategy over the past four decades coupled with innovations in technology has revolutionised management of enterprises tremendously. The SCM strategy has enhanced supplier-customer collaboration and integration in the delivery of product/service to ultimate customers, while the enabling role of technology speeds up the information and product flow. The effectiveness and efficiency emanating from supply chain management is a manifestation of enterprises' inclusive concern of value-creation from economic, environmental and social attributes, also referred as triple-bottom line (TBL). Such enterprises are streamlined as they utilise resources sparingly and produced less waste. Hence, they are lean, resilient and possess capacity to withstand disruptions. These qualities are derived from green initiatives and render these enterprises' competitiveness and sustainability. This is change management through which conventional supply chain management transforms into green supply chain management (GSCM) by refocusing value-creation in embracing the triple-bottom line that drives the competiveness and sustainability of enterprises.

Keywords: competitiveness, green initiatives, GSCM, SCM, sustainability, triple-bottom line

1. Introduction: The advent of supply chain management and innovations in technology

The enterprises have gone through tremendous transformation in the last four decades from the emergence of supply chain management (SCM) strategy and intensification of technology application [1]. The last few decades have seen the emergence of the global value chains (GVCs) from global manufacturing facilities that produce and supply products for the global markets [2]. Aligned with these occurrences are innovations in information technology that has continued to speed up information and products flow along the supply chain network. The conventional supply chain management thrives via enhanced communication that drive supplier-customer relationship through increased cooperation, coordination, collaboration and integration ([3], p. 49). Cooperation entails working together of supply chain partners, while coordination is an improved working relationship among the supply chain partners.

Supply chain collaboration (SCC) is "the establishment of working relationship of an enterprise with a supplier organisation, whereby two organisations act as one" ([4], p. 171). This relates to supplier-customer relationship and other stakeholders in the supply network ([3], p. 47). described SCC as "a relationship between supply chain partners developed over time". Hence, time is of essence for the existence of enterprises in SCC, which depicts their sustainability.

Supply chain integration (SCI) is "the alignment and interlinking of business processes" [5]. The integration process is information technology (IT) driven via four intangible variables: coordination, cooperation, information sharing and information visibility, which are enablers of supply chain [6]. The SCI along supply chain network includes increased communication within firms and across teams, functions, processes and external firms over time and is technology driven ([7], p. 152). The supply chain network incorporates the forward flow from supply side to the demand side and vice versa for the backward flow or reverse logistics. In the fast moving consumer goods (FMCGs) supply chain, the collaborative planning, forecasting and replenishment (CPFR) of inventory in the retail chain outlets elaborates the role of SCI ([4], p.172). The CPFR is a technology driven process between the retailers, distribution centres and suppliers that ensures timeous and continuity of inventory supply. The availability of inventory when needed is a competitive advantage that drives sustainability of the retail enterprises for ensuring continuous trading.

The FMCGs industry's adoption of technology has transformed their distribution channels to include Omni-channel which is also a part of green initiatives as it increases sales through a streamlined online process [8]. "Omni-channel is a direct to consumer (D2C) business model where all sales channels: online, mobile, telephone, mail-order, self-service and physical retail establishments are aligned to provide to provide integrated service to consumers" ([9], p. 118). This unique role of technology drive competitiveness and sustainability of enterprises as the response time to customers is shortened translating into increased turnover and continuity in operations [10].

Technology is an enabler of supply chain management as it integrates the supply chain partners for faster transactions and provides visibility of processes at various stages in the supply chain ([11], pp. 38–59). The global implementation of the fourth industrial revolution (4IR) is hoped to speed up SCM processes, render them agile, focused and more sustainable [12]. At the moment, computers are used in most enterprises to connect with the world wide web for internet access. Some of the technology application in supply chain comprises the following:

Electronic data interchange (EDI): A computer to computer exchange of business documents such as purchase orders, order status enquiries, reports, promotion announcements, shipping and billing notices ([3], 232).

Barcode: A series of alternating bars and spaces printed or stamped on parts, containers, or labels representing encoded information that can be read by electronic readers. It is used for timely and accurate input to a computer system ([4], p. 12).

Radio frequency identification (RFID): A WI-FI-enabled radio frequency identification tags to allow tracing of items in real time.

Warehouse management systems (WMS): A software control system that improves product movement and storage operations through efficient management of information and completion of distribution tasks [13].

Transport management systems (TMS): A computer application system that is designed for the management of transportation using modules that focus on specific functions such as intermodal transportation, fleet service management, load planning and optimisation among others ([4], p. 181).

Global positioning systems (GPS): It is used for tracking vehicles such as the delivery trucks ([4], 72).

2. Competitiveness and sustainability in enterprises

The provisions of customer satisfaction, building conducive working environment with stakeholders and profitability underpins the essence of any business. Enterprises endeavour to provide quality products/services to the end customers in the most ethical ways that guarantee business continuity and environmental compliance, that culminated to competitiveness and sustainability. These dependent variables are achieved when enterprises strive to optimise returns with minimum resources, while focusing on economic, social and environmental attributes ([14], p. 9).

3. Global competitiveness

The world has traded from as early as the Middle Ages when people moved between countries in search of scarce commodities which were exchanged through barter trade [15]. With improved infrastructure powered by innovations in technology globalisation has hiked the global trade due to enhanced connectivity among nations, becoming popularly referred as a global village. The economic theories attest to the global trade and commerce as indicated by some old and new economic theories. The Adam Smith's "Theory of Absolute Advantage" is still valid in its reference that "countries would trade better if they traded commodities that had an economic or cost advantage for one or more products they produced" ([9], p. 29). Another economic theory, "Factor Endowment Theory" postulates that nations have a competitive advantage in producing one or more products when they possess one or more factors of production: land, labour, capital and entrepreneurship [16].

These are the parameters upon which global value chain and globalisation has developed. Global enterprises strive to be competitive by being low cost producers or supplementing through import or outsourcing from other low cost producers such as China [17]. These economic principles, social and environmental attributes are the underlying objectives of GSCM and portrays the enterprises' competitiveness and sustainability.

4. Competitiveness

The competitiveness of supply chain is informed by Porter's strategies of cost and differentiation for distinguishing between conventional supply chain and green supply chain management. The GSCM is technology driven and aims for higher productivity, efficiency and capacity utilisation. It also aims for lower cost for facilities, materials and labour and effective distribution channels ([18], pp. 455–468).

Porter [19] (2008) described that value chain should display total value through value activities. The value activities were referred as physical and technologically distinct activities a firm perform as in the use of green initiatives such as application of technology, optimised transportation and emphasis on corporate social responsibility (CSR) among others. [20] described most industries including FMCGs, has five activities which act as the pillars of competitive advantage. They comprise of:

Inbound logistics: the activities associated with the supply of raw materials to the manufacturing enterprise. Also included are material handling, warehousing, inventory control, vehicle scheduling and returns to the suppliers.

Operations: It deals with the transformation of inputs (raw materials) into final products. The activities include production process, packaging, assembly, equipment maintenance, testing and printing.

Outbound logistics: These are activities associated with collecting, sorting and physical distribution of products to the buyers or customers, distribution centres DCs), material handling, delivery vehicle operations, order processing and scheduling.

Sales and marketing: These are the activities such as selling to customers, quoting, pricing, advertising, promotion, channel selection and channel relations.

Service: This includes service provisions, maintaining value of products including installations, repair, training, part supply and product adjustment.

5. Sustainability

Sustainability is described as factors which enable enterprises to withstand, maintain or prolong existence ([21], p. 44). These factors include the choice of renewable energy and the use of renewable raw materials that has minimal carbon emissions. Renewable energy is produced from natural sources such as solar, wind, hydro power and bio-diesel which has minimal carbon emissions. The renewable raw materials are those which produce products which at the end of life can be recycled or remanufactured into new products. Mitigating damage to the environment by reducing carbon emissions through logistics roles in sourcing, transportation and warehousing are green initiatives which render enterprises sustainable ([14], p. 11). This entails sourcing from suppliers who use renewable raw materials, practice ethical labour standards and use transportation that minimise carbon emissions ([22], p. 25).

([17], p. 110) concurred with the definition of sustainability by [23] as "the ability to meet needs of the current supply chain members without hindering the ability to meet the needs of future generations in terms of economic, environmental and social challenges". The enterprise's accountability of economic, environment and social are sustainability attributes, referred to as 'triple-bottom line' (TBL). This happens when there is close working relationship between the enterprise, suppliers and other role players or collaboration of all the parties involved in the supply chain ([21], p. 107). The enterprise's drive to optimise returns with minimum resources results in competitiveness and sustainability ([14], p. 9).

6. Green initiatives in supply chain management

The green initiatives in supply chain involve changes in conventional supply chain management (SCM) to green supply chain management (GSCM). ([24], p. 785) define change management as "the tools, techniques and processes that scope, resource and direct activities to implement a change". The change from conventional supply chain comprises of initiatives that involve sharing of environmental responsibility with the value chain (VC) partners in purchasing, manufacturing, materials management, distribution and reverse logistics ([7], p. 508). Value chain incorporates primary activities that provide enabling business environment in the development of sustainable competitive advantage. The activities create customer supported value such as marketing, product design, production and delivery [25]. The American Production and Inventory Control Society (APICS) define green supply chain management as "a supply chain that considers environmental impacts on its operations and takes action along the supply chain to comply with environmental safety regulations and communicate this to customers and partners" ([4], p. 73).

The full range of activities undertaken by firms and workers to initiate and develop a product and processes through its life cycle and beyond are the framework

of a value chain. The process pattern commences with design, production, marketing, distribution and through to support provided to the final consumer ([26], pp. 129–133). ([14], p.17) expressed the principle of GSCM as the 'green initiatives' factors comprising of dematerialisation, detoxification and decarbonisation that streamline operations towards sustainability. Dematerialisation entails reducing the amount of materials or time needed to produce and deliver products/services required by the customer. Detoxification entails reduction of pollutants from hazardous materials and industrial products. Decarbonisation or de-energisation refers to mitigation of carbon emissions in an organisation by using renewable energy and utilising processes with less carbon emissions.

The sharing of environmental responsibility entails utilisation of materials, products and processes which has less carbon emissions as it exacerbates the climate change or global warming (UNFCCC 2010). Examples of GSCM applications include the use of renewable energy, bio-diesel for transportation, use of appropriate mode of transportation that reduces cost and/or emissions reduction, use of full container load both ways where applicable and others ([21], p. 111).

Essentially, the green initiatives or green supply chain management facilitate optimisation in enterprises functions, reduction of waste and cost rendering the operation competitive, profitable and ability to continue or sustainable ([25]. [9], p. 615) described GSCM as a closed-loop supply chain as it is concerned with both forward and reverse movement of products. In closed-loop supply chain, the emphasis is on reducing cost and capturing value as the ultimate goal of the manufacturer is for everything to be reused or recycled ([18], pp. 455–468).

Developing the green initiatives or GSCM requires an elaborate system factoring in all the supply chain processes. They include planning for procurement, production, packaging, product sales and marketing, logistics and product life management [18], pp. 455–468). The next stage comprises of preparation of a detailed implementation plan factoring the environmental impact, economic and social attributes which is technology driven. ([14],11) provided a GSCM system featuring supply chain network processes as follows:

Planning for procurement: planning involves training employee training in the best practices in supply chain management; involving suppliers in decision-making; developing alternatives for performance improvements and organisational alignment for continuous improvement.

Production: process design, categorising and identifying environmental impact and cost and adopting the most economical and environmental friendly process; and involving suppliers/vendors in decision-making.

Packaging: minimising resources and hazards; recycling and energy recovery; usage of reusable and recyclable packaging; waste reduction, customers' collaboration and regular audits and performance review.

Product sales and marketing: creating awareness among consumers of green products; emphasis on eco-friendly products and clear communication between suppliers and logistics providers.

Logistics: rail as preferred mode of transportation and third-party logistics (3PL) recommended; logistics optimisation, use of clean fuel, optimised truck load and collecting waste; use of distribution centres (DCs) for fast moving consumer goods (FMCGs).

Product end-of-life management: product design, supply and effectiveness; reprocessing end-of-life products' materials for economic recovery.

The GSCM pursue materials and processes that minimise the impact on the environment. The main considerations are reduction in the amount of raw materials used; minimising the number of components in the product; minimising energy consumption; increasing the useful life cycle; maximising use of renewable and

recyclable materials and minimising the environmental footprint and sustainability of each [26]. Green supply chain management extends across an enterprise, its trading partners, the processes involved in purchasing, manufacturing, materials management, distribution and reverse logistics. Hence, GSCM is also describe as a closed-loop supply chain which is designed to manage both forward and backward (reverse) flows ([9], p. 64).

7. Environmental implications

Environmental concerns refer to cognition in the use of green products for protection of the environment ([21], p. 18). Environmental protection is stipulated in the biosphere rules that enterprises are required to pursue to avoid environmental degradation. The biosphere is the earth's surface and atmosphere inhabited by living things which is also the environment in which enterprises operate ([14], p. 171).

In his book on "Earth Incorporated", ([21], p. xviii) described five rules or principles of biosphere as materials parsimony, power autonomy, value cycles, sustainable product platforms and function over form.

- **"Materials parsimony**: The focus is on the need to minimise the types of materials used in products especially those which are life-friendly and economically recyclable. In implementing this rule, an enterprise would realise reduced supplier complexity, reduced production complexity, reduced toxic risk, reduced compliance costs, volume purchase discount, improved health and safety, improved work productivity, improved products attributes and improved environmental performance.

- **Power Autonomy**: To reduce energy costs with the use of renewable energy for production processes.

- **Value cycle**: Involves product recovery from recycling and remanufacturing as a value-added process.

- **Sustainable product platforms**: Benchmarking to improve product benefits in scale and scope and gain knowledge and experience by doing.

- **Function over form**: Fulfil customer functional needs in ways that sustain value cycle".

Towards a sustainable enterprise

([21], p. xviii) expressed some crucial factors pursued in realisation of a sustainable enterprise:

- Involvement of all value chain partners.

- A strategic plan to be prepared and pursued.

- Highlighting awareness of climate change (reduction of carbon emissions, energy efficiency and so on)

- Waste must be recycled, reused and reduced

- Intensify use of natural resources such as water and renewable sources of energy

- Enforce supplier ethical assessment and collaboration

These activities streamline enterprises making them to undertake only the crucial functions, minimising resources through reuse and recycling and intensify use of natural resources such as water and renewable energy that has less carbon emissions. The sharing of environmental responsibility in supply chain at every stage and process ensures minimisation of adverse impact on the environment ([7], p. 508). These are risk mitigation processes that make enterprises more sustainable and more competitive through cost saving, business differentiation and attracting more customers which are characteristics of GSCM ([22], p. 27).

8. Supply chain risk/disruption

The words risk, disruption and vulnerability describe occurrences with negative consequences and they help describe such situations in supply chain. The English dictionary define risk as the possibility of incurring misfortune or loss; disruption is an interruption of progress of something; and vulnerability means exposure to attack.

Supply chain risk "comprises of a number of events and their outcomes that could have a negative effect on the flow of goods, services, funds or information resulting in some level of quantitative or qualitative loss for the supply chain" ([27], p. 172).

Supply chain disruption are risk occurrences such as sudden fall in prices or natural disasters such as earthquakes, floods and disease pandemic ([9], p. 44).

Supply chain vulnerability describes broader perspectives of risk embraced in SCM networks involving products/services, process performance, trading relationships, currency fluctuations among others ([4], p. 172).

In supply chain management, risk refers to a particular type of hazard or threat such as technological, political, terrorism and natural disasters among others. The supply chain risk also manifests as financial loss or competitive disadvantage resulting from a failure to implement 'best practice' in SCM ([3], p. 308).

([7], p. 481) described the processes of supply chain risk mitigation to include the following:

"**Increasing safety stock and forward buying**: It calls for extra expenses, but a crucial alternative as countries have experienced in beefing up medical equipment and food supplies during 2019/2020 Covid-19 global pandemic.

Identify backup suppliers and logistics services: Over-dependence on China as key global supplier of general goods and the slowing down of logistics activities to contain the spread of the Covid-19 pandemic.

Diversify supply base: The importance of multiple suppliers from geographically dispersed markets to minimise disruptions.

Utilise supply chain IT system: The use of information technology (IT) enhance collection and sharing of crucial information with supply chain partners.

Develop a formal risk management programme: Helps identify potential disruptions and the appropriate response".

The supply chain risk adversely impacts on enterprises financially, reputation and customer service among others [4]. As supply chains grow to include more international suppliers and customers, the complexity of disruption increases ([7], p. 480).

The Covid-19 pandemic of 2019/2020 exposed vulnerability and rendered many global organisations vulnerable. The global FMCGs suppliers and traders that relied heavily on imports from China which has hitherto turned like global manufacturing centre had their supply chain disrupted by the pandemic [28]. The leading role of China in global supply chain was reaffirmed in a 2020 report by Deloitte Canada which referred to supply chains mostly disrupted as for those countries that had China as their tier 1 (direct) or tier 2 (secondary) supplier [29]. The tier 1 suppliers supply raw materials direct to the focal firm or manufacturer and tier 2 suppliers supply to tier 1 suppliers ([9], p. 153).

9. Green logistics management

Logistics management is a crucial component of SCM which is responsible for forward, reverse transportation and warehousing functions ([7], p. 336). Logistics management is defined as "that part of supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to point of consumption in order to meet customer requirements" ([4], 94).

The GCSM involves environmental considerations in purchasing, manufacturing, materials management, distribution and reverse logistics ([14], p. 17). Thus, green logistics management pursues green initiatives through green transportation, green warehousing and green reverse logistics to drive sustainability in the supply chain. The optimised processes in supply chain such as transportation, warehousing and information flow through technology applications streamlined enterprises into hardened status and able to withstand disruptions. These are characteristics of GRSCM [30].

The green logistics role is accomplished through logistics seven Rs (7Rs), translated as: "getting the right product to the right customer, in the right quantity, in the right condition, at the right place, at the right time, and at the right cost". The 7Rs eliminates waste which is a prerogative of green logistics to create value for the customer and render an enterprise more sustainable [31]. Pursuing a similar trend, green reverse logistics is concerned with returned materials that undergo through processes of recycling, reusing, refurbishing and disposal in landfill, reducing environmental pollution ([21], p. 74).

10. Reverse logistics and 3Rs

Reverse logistics involves the processes of sending new or used products "back upstream" for repair, reuse, refurbishing, resale, recycling, scrap or salvage [9], p. 614). Items are usually returned to a central location for processing which involves transportation, receiving, testing, inspection and sortation for appropriate action such as repair, refurbishing or resale. The facility and related processes are provided either by the original manufacturer or a third-party logistics (3PL) company.

The philosophy of "cradle-to-cradle" describe how enterprises are able to recover resources or value from the returned or damaged products. The philosophy or protocol of cradle-to-cradle is derived from nature, whereby one creature's waste is another's food ([21], p. xiv). The three 3Rs of reverse logistics: return, recycle and resale generate value from the damaged products which could have ended in landfills ([14], p. 125).

The reverse logistics system transforms into green reverse logistics when the system "start focusing on reducing the environmental impact of certain modes of transportation used for returns, reducing the amount of disposed packaging

and product materials by redesigning products and processes and making use of reusable totes and pallets" ([7], p. 530). Therefore, the pursuit of reverse logistics in GSCM is a value adding process through which enterprises received resources which could have gone to waste, driving competitiveness and sustainability.

11. Lean and agile approaches

The principle of lean thinking is to improve material flow and minimise waste, while ensuring customer value delivered. Lean management was started in Western Europe after just-in-time (JIT) approach in Japan in 1950s. The two concepts mean the same as they aim to minimise space, resource and inventory in pursuit of minimising waste [21], p. 47). Waste in supply chain comprise the following:

Transportation: unscheduled transportation, double handling and unnecessary movement of folk-lift truck among others.

Waiting: occurs where time is not used effectively.

Overproduction: producing in excess of the orders received add cost of warehousing awaiting new orders.

Inappropriate processing: using a large central process meant for several items to process number of items below economic level.

Unnecessary inventory: inventory resulting from overproduction that has additional cost of warehousing until orders are received.

Unnecessary motion: walking between processes unnecessarily like delivering documents to other work centres that could have been emailed.

Defects: production of products that do not meet specifications and of low quality.

The concept of agile supply chain is about having an end-customer focused supply chain as opposed to conventional supply chains which are structured around the focal firm [32]. It is essentially an approach to organising logistics capabilities around changing end-customer demands and responding timeously. In manufacturing, agility is defined as "the ability to successfully manufacture and market a broad range of low-cost, high-quality products and services with short lead times and varying volumes that provide enhanced value to customers through customisation" ([4], p. 6).

12. Supply chain resilience

Supply chain resilience is the ability of supply chain to respond to risk/disruption and recovering fast from these disruptions to return back to its original state better prepared to optimise customer service and financial stability ([33], pp. 109–122). The resiliency in supply chain was described by APICS as "the ability to return to a position of equilibrium after experiencing an event that causes operational results to deviate from expectations". This is what happened to enterprises in the period of global Coronavirus pandemic in 2020. [34] described supply chain resilience as "the ability to exploit the disruptions as a competitive advantage to excel over the competitors through redundancy, building flexibility and changing corporate culture".

Redundancy: Redundancy in supply chain requires holding higher level of inventory, maintaining low utilisation capacity and maintaining several suppliers that increases the operations cost. However, efficiency is achieved through utilisation of lean production processes.

Flexibility: Supply chain flexibility involves aligning procurement strategy with supplier relationship and adapting to postponement plans.

Cultural change: Stepping up communication with employees to condition them to familiarise with disruptions and be passionate about their work.

The period of supply chain disruptions in 2020 due to the global Coronavirus pandemic required resilience practice in enterprises to withstand unusual occurrence. Enterprises experienced redundancy with several employees losing jobs and bonded closely with the remaining employees most of whom worked remotely from home. As a result, flexibility ensued as enterprises repurposed and prioritised procurement of food and medical supplies as essential commodities [35].

This attribute of GSCM is lean as it is able to deliver products quickly to the end customers as it has streamlined procurement, quality and precision manufacturing, low level of inventory and use of consolidated transportation where multiple products use single shipment [36]. ([9], p. 180) describes seven types of waste that a lean supply chain controls: overproduction, delays (process and parts), transportation, over-processing, inventory levels, motion (unnecessary movement of parts in production) and making defective parts.

13. Corporate social responsibility in supply chain

Corporate social responsibility (CSR) is a practice of business ethics that required enterprises to act responsibly by observing the attributes of environment, social and economics referred to as triple-bottom line (TBL) [7]. (Wisner, Tan & Leong, 2016:106). In supply chain, emphasis is placed on ethical sourcing as it impacts on public, buying organisation and the suppliers. This is to ensure ethical processes are followed and the enterprise can express other benefits such as the environment and the community that interact together with the underlying economic benefits [37].

([22], p. 25) provided the parameters of CSR that included activities aimed at extending the outreach and existence of an enterprise as follows:

- Factoring society and community in the long-term plan.
- Controlling hazardous chemicals in products and other waste that impacted on the environment and minimised environmental pollution (air, water, soil, noise). Promotion of resource and energy saving by reusing, reducing and recycling; greenhouse gas production; waste reduction and disclosed environmental preservation activities.
- Advocated the protected computer networks against threats for information security.
- Encouraged fair trading by prohibiting corruption and bribery, abuse of superior positions and provided correct information on products/services among others.
- Provision for occupational health and safety at workplace.
- Promotion of human rights by prohibiting forced labour, inhuman treatment, child labour, discrimination and payment of appropriate wages. CSR also advocated the provision of conducive working environment, hours of work and allowing freedom of association.

These attributes drive sustainability and they also provide competitive advantage to the organisation.

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References

[1] Ostidick N. How technology is reshaping today's supply chain. The Supply Chain Manager's Guide to Industry 4.0. 2017. Available from: https://blog.flexis.com/how-technology-is-reshaping-todays-supply-chain [Accessed: 06 September 2020]

[2] Shinozawa Y. Theory of International Values, A new Construction of Ricardian Theory of International Values. Singapore: Springer, 2017

[3] Mangan J, Lalwani C, Butcher T, Javadpour, R. Global Logistics & Supply Chain Management. 2nd ed. Wiltshire, UK: John Wiley, 2012

[4] American Production and Inventory Control Society (APICS). The Essential Supply Chain Reference (Dictionary). Terry College of Business, University of Georgia Press, 2013

[5] Yang C-H, Jung C. The antecedents and consequences of supply chain service capabilities in the context of container shipping. The International Journal of Logistics Management. 2016; 27(2):236-262

[6] Silvestro R, Lustrato P. Integrating financial and physical supply chains: the role of banks in enabling supply chain integration. International Journal of Operations & Production Management. 2014; 34(3):298-324

[7] Wisner, J. D., Tan, K-C. & Leong, G. K. Principles of Supply Chain Management: A Balanced Approach. 4th ed. Boston, MA: Cengage Learning, 2012

[8] Furness D. 2018. Streamline your success with Omni-channel marketing. [Online] Available from: https://esellercafe.com/streamline-your-success-with-omnichannel-marketing/ [Accessed: 09 October 2020]

[9] Coyle JJ, Langley CJ, Novack RA, Gibson, BJ. Supply Chain Management: A Logistics Perspective. 10th ed. Boston, MA: Cengage Learning, 2017

[10] Stockpole B. 5 Supply chain technologies that drive competitive advantage, 2020. [Online]. Available from: https://mitsloan.mit.edu/ideas-made-to-matter/5-supply-chain-technologies-deliver-competitive-advantage [Accessed: 03 October 2020]

[11] Fawcett SE. Information technology as an enabler of supply chain collaboration. Journal of Supply Chain Management. 2011; 47(1): 38-59

[12] World Economic Forum (WEF). Impact of the fourth industrial revolution on supply chains. 2017. [Online]. Available from: https://www3.weforum.org/docs/WEF_Impact_of_the_Fourth_Industrial_Revolution_on_Supply_Chains_.pdf., 2017 [Accessed: 19 September 2020]

[13] McCrea B. Warehouse management systems (WMS)/Inventory management technology: 6 trends for modern age. Logistics Management, 2018. Available from: https://www.logisticsmgmt.com/article/warehouse_ management_wms_inventory_management_technology_6_trends_for_the_m. [Accessed: 07 April 2020

[14] Wang H-F, & Gupta SM. Green Supply Chain Management: Product Life Cycle Approach. New York: McGraw Hill, 2011

[15] Irwin DA. A brief History of International Trade Policy. 2001, Available from: https://www.econlib.org/library/Columns/Irwintrade.html [Accessed: 08 October 2020]

[16] World Trade Organization (WTO). International trade statistics new

archive. 2020. [Online]. Available from: https://www.wto.org/english/news_e/archive_e/stat_arc_e.htm [Accessed: 14 October 2020]

[17] Ragland C, Wimier S, Brouthers LE. A factor endowment approach to international market selection. Journal of Strategic Marketing, 2015; 23(6): 1-15

[18] Kumar NR, Satheesh Kumar. Closed loop supply chain management and reverse logistics – A literature review. International Journal of Engineering Research and Technology, 2013, pp. 455-468

[19] Porter ME. 2008. Competitive Advantage: Creating and Sustaining Superior Performance. New York: Free Press, 2008

[20] Sehgal V. Supply Chain as a Strategic Asset: The Key to Reaching Business Goals, 2010. Wiley, Available from: https://books.google.co.za/books?id=8TZpDwAAQBAJ&pg=PA56&dq=inbound+logistics,+outbound+logistics,+operations+supply+chain+functions&hl=en&sa=X&ved=2ahUKEwin7tmJ2KfsAhXbPsAKHZQBDa4Q6AEwBHoECAQQAg#v=onepage&q=inbound%20logistics%2C%20outbound%20logistics%2C%20operations%20supply%20chain%20functions&f=false [Accessed: 09 October 2020]

[21] Unruh G. Earth, INC. Boston, MA: Harvard Business Press, 2010

[22] Harrison A, Van Hoek RI, Skipworth H. Logistics Management and Strategy: Competing Through the Supply Chain. 5th ed. Edinburgh Gate, Harlow (UK): Pearson Education, 2014

[23] Brundtland GH. United Nations Report on sustainable development, 1987 [Online] Available from: https://www.britannica.com/topic/Brundtland-Report, [Accessed: 03 April 2020]

[24] Cummings TG, Worley CG. 2015. Organization Development & Change. Stamford, CT: Cengage Learning, 2015

[25] Swenson B. 10 Steps of reducing costs while saving the environment. Allbusiness.com. 2020. Available from: https://www.allbusiness.com/10-steps-to-reducing-costs-while-saving-the-environment-7310546-1.html, [Accessed:23 September 2020]

[26] Paksoy T, Huber S, Weber G-H. Lean and Green Supply Chain Management: Optimization Models and Algorithms, 2018. Available from: https://books.google.co.za/books?id=ZWJ5DwAAQBAJ&printsec=frontcover&dq=requirements+for+green+supply+chain+management&hl=en&sa=X&ved=2ahUKEwi2kbyd36fsAhXJilwKHV6TD7EQ6AEwCHoECAkQAg#v=onepage&q=requirements%20for%20green%20supply%20chain%20management&f=false Accessed: 09 October 2020]

[27] Trent RJ, Roberts LR. Managing Global Supply Chain Risk: Best Concepts and Strategies. Fort Lauderdale, FL: Ross Publishing, 2010

[28] World Economic Forum (WEF). COVID-19 implications on manufacturing and supply systems. 2020. [Online]. Available from: https://www.weforum.org/projects/reshaping-global-value [Accessed: 16 September 2020]

[29] Deloitte Canada. When China, the world's factory, is impacted, global supply chains are impacted, 2020. [Online] Available from file:///C:/Users/35565039/AppData/Local/Temp/sea-about-covid-19-managing-supply-chain-risk-disruption.pdf. [Accessed: 16 September 2020]

[30] Bowles R. Optimize your inbound logistics and outbound logistics to

increase profitability, 2020. Available from: https://www.logiwa.com/blog/inbound-outbound-logistics [Accessed: 03 October 2020]

[31] Christopher M. Logistics & Supply Chain Management. 5th edition. E-book. Pearson. 2016 [Online] Available from: https://www.bookdepository.com/Logistics-Supply-Chain-Management-Martin-Christopher/9781292083797 [Accessed: 20 September 2020]

[32] Van Hoek RI. The agile supply chain. Physical Distribution & Logistics Management, 2006; 36(6): 415-455

[33] Ribeiro JR, Barbosa-Povoa AP. Supply chain resilience: Definitions and modelling approaches – a literature review, 2018. [Online]. Available from: https://www.researchgate.net/publication/320901897_Supply_Chain_Resilience_Definitions_and_Quantitative_Modelling_Approaches_-_a_literature_review, [Accessed: 16 September 2020]

[34] Michelman P. Building a resilient supply chain. Business Review, 2007, Available from: https://hbr.org/2007/08/building-a-resilient-supply-ch%20May%2011. [Accessed: 30 September 2020]

[35] World Health Organisanization (WHO). COVID-19 – a global pandemic. 2020. [Online]. Available from: https://africacheck.org/fbcheck/yes-world-health-organization-declared-covid-19-coronavirus-outbreak-a-pandemic/ [Accessed: 16 September 2020]

[36] Murray M. Creating a lean supply chain. The Balance Small Business, 2019. [Online]. Available from: https://www.thebalancesmb.com/lean-supply-chain-management-2221274 [Accessed: 18 September 2020]

[37] United Nations Industrial Development Organization (UNIDO). Corporate social responsibility to help enterpsrises achieve SDGs. 2015. [Online]. Available from: https://www.unido.org/news/corporate-social-responsibility-help-enterprises-achieve-sdgs [Accessed: 06 October 2020]

Chapter 6

The Impact of Industry 4.0 on the Future of Green Supply Chain

Tamás Bányai and Mohammad Zaher Akkad

Abstract

The fourth industrial revolution offers new technologies to transform conventional supply chain solutions into cyber-physical supply chain ones. This transformation makes it possible to increase the efficiency, availability, quality, and cost-efficiency of the value-making chain, while the energy consumption and the GHG emission can be decreased. Within the frame of this chapter, the authors introduce the most important Industry 4.0 technologies and Internet of Things tools and demonstrate their potentials to update supply chain operations. This update of conventional operations can lead to greener and more sustainable purchasing, production, and distribution processes. The successful future of the green supply chain is based on a wide range of factors, like production management, logistics management, societal and regulatory environment. However, the Industry 4.0 technologies are expected to strongly influence the whole supply chain performance positively. This chapter aims to explore the potentials of Industry 4.0 technologies and the transformation of conventional supply chain solutions into cyber-physical systems, especially from a municipal waste collection point of view. The research findings can provide useful insights for supply chain experts, manufacturing, and service companies.

Keywords: cyber-physical system, green supply chain, Industry 4.0, Internet of Things, logistics, sustainability

1. Introduction

Green supply chain refers to convert the traditional supply chain process into a sustainable environment-friendly one. Sustainability covers a wide comprehensive that includes the concept of "green in" systems, which means reducing energy and resource consumption and wastage in processes, next to the context of "green by" systems, which covers human and economic improvements. Sustainability can be considered within five dimensions mainly are human, social, technical, environmental, and economic [1]. These dimensions are interconnected with each other directly or indirectly, therefore, one dimension of sustainability cannot be reinforced without considering others. In addition, other concepts connect sustainability and the supply chain. For instance, Circular Economy (CE) and reverse logistics (RL). Circular systems aim to eliminate waste and to have continuous use of resources by applying reuse, share, repair, refurbishment, and recycle approaches to create a closed-loop system, which minimizes the use of resource inputs and reduces waste scraps, pollution, and carbon emissions. Reverse logistics was defined [2] as "the process of planning, application, control of the operation, cost and flow of raw materials, the inventory process, finished products, the information related,

from the point of consumption to the point of origin, in order to recover or create value or proper disposal". RL is considered as product return management, real-time inventory and workflow, tracking warranties, ordering and exchange parts, the flow of materials and information, data analysis, execution of repairs, customer notification, and all the logistics return flow.

Within the frame of our research work, we have used the systematic literature review methodology to identify the most important research topics regarding industry 4.0 in green supply chain solutions and to find potential research gaps. Within the frame of our systematic literature review, we have formulated research questions, selected sources from Web of Science and Scopus, and analyzed them. We have used the following keywords to search in the mentioned database: TOPIC: ("industry 4.0" and "green supply chain" or "green logistics"). Initially, 48 articles were identified. This list was reduced to 40 articles selecting journal articles in English only. Our search was conducted in January 2021; therefore, new articles may have been published since then.

Figure 1 shows some approaches focusing on the impact of Industry 4.0 on green supply chain solutions, including the following aspects: environmental consideration [3], IoT technologies and green supply chain [4], business logistics and circular economy [5], drivers of Industry 4.0 and circular economy [6], diffusion of green products [7], sustainable business models [8], pilots and applications [9, 10], lean paradigm in green supply chain [11, 12]and supply chain performance [13].

We can analyze the available sources from multidisciplinary point of view. The green supply chain problems include a wide range of scientific problems, including inoovation management [14], price balancing [15], fuzzy optimization [14, 16–18], impact of manufacturing on environment [19], collection channel

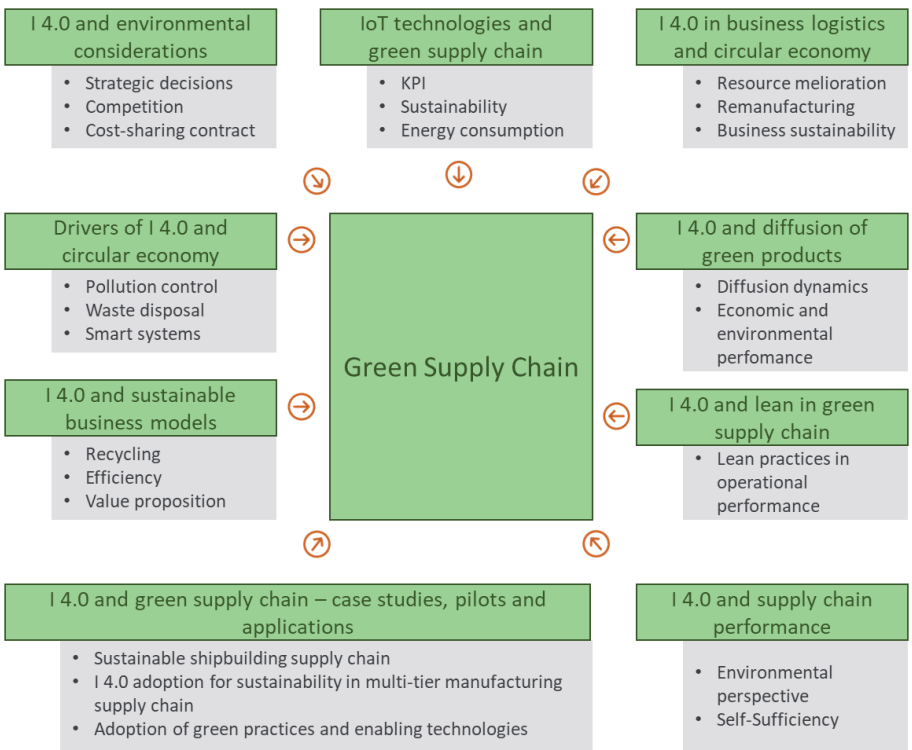

Figure 1.
Relationships between Industry 4.0 technologies and green supply chain from the literature review point of view.

design [20], cross-shareholding problems [21], big data and artificial intelligence applications [22], dual channel supply chain design [23, 24], integrated optimization of green supply chain operations including routing and scheduling [25], social impact of greening [26], and green water transfer design [27]. These aspect are analyzed in different case studies [28–30].

On the other hand, the term industrial revolution represents a quantum leap in the industry, which means raising the quantity, quality, or both in the industry and adopting innovative industrial methods through new technologies. Modern digital technologies, such as cyber-physical systems (CPS), the internet of things (IoT), and the internet of services (IoS) represent new models that are fast gaining ground in industrial transformation in the last few years [31]. So far, there have been three industrial revolutions. We are now in the midst of the Fourth Industrial Revolution, or briefly called "Industry 4.0", which is now being developed and dominated by the different industrial sectors comprehensively. The most prominent feature of Industry 4.0 is the adoption of intelligent technologies that rely on the Internet of Things and remove the lines that separate the physical, digital, and biological areas [32]. Industry 4.0 applications include the most recent technologies, especially in telecommunications, the internet, and nanotechnology, which allowed us to use small devices with great efficiency [33]. This combination of advanced technologies supported obtaining various applications that have revolutionized the world of industry and changed the traditional concept of communication between machine and human into having the concept of communication between machine and machine [34, 35]. It is possible to argue that Industry 4.0 technologies can pave the way for green supply chain management, for example by tracking products post-consumption to recover components. Nevertheless, due to the very recent development of these ideas, the relationship between the green supply chain and Industry 4.0 technologies has not been widely evaluated in the literature or practice, even though the two topics have been analyzed separately. As the main finding, Industry 4.0 has wide influence and effects because of its numerous modern applications that come from the recent technological revolution. These technologies are being developed based on interconnecting different areas, linking the fields of artificial intelligence, information technology, logistics and supply chain systems, and environmental engineering to each other. On the other side, sustainability is an inclusive term that includes many dimensions with an increasing interest in using it to reach a better world. The green supply chain is expected to be significantly affected by Industry 4.0 in an accelerated way especially with the increased interest for using those new technologies to support sustainability by increasing the efficiency, reliability, and flexibility all along with saving energy and time with protecting the environment. To clarify the possibilities in this manner, we will describe a few of the Industry 4.0 technologies that support developing the green supply chain and adopting cyber-physical systems that raise sustainability. In addition, a few examples of green supply chain applications within the industry 4.0 environment are also to be discussed.

2. Industry 4.0 technologies

Industry 4.0 applications include the most recent technologies, especially in telecommunications, internet, and nanotechnology areas, which allowed us to use small devices with great efficiency. This combination of advanced technologies supports obtaining various applications that have revolutionized the world of industry and changed the traditional concept of communication between human and machine into having the concept of communication between machine and machine. It is easy to observe the rapid pace of development of the industry, which makes it imperative to follow up on the new applications of Industry 4.0 eagerly for keeping

abreast of this development and benefit from it. We can consider the following technologies as the tools that may move the green supply chain to the next level.

2.1 Internet of things

Internet of Things or IoT is an emerging term that we can describe as the new generation of the internet network that is linking directly the interconnected devices. These devices include instruments, sensors, artificial intelligence tools, or other smart devices. This definition goes beyond the traditional concept of connecting people with smart devices over a single network to reach having all devices that can work on the internet and that can collect, send, and process the data that they capture from their surrounding environment using built-in sensors and processors in addition to communication media. They are often called connected or smart devices because they can communicate with other devices connected to them in a process known as machine-to-machine communication. Once several devices can work together, and even with devices from different manufacturers, we will be able to complete many of the daily tasks. IoT is also distinguished by allowing people to be free from the specified place. Therefore, the person can control the tools without being in a particular location, taking into consideration that the harmony between the devices is direct and that the person is one of the nodes of communication like other terminals. The connected things here mean any device or peripheral that can be identified on the internet by an IP address such as a car, television, or any household appliances such as refrigerator, washing machine, alarms, doorways, and air conditioners. It also extends to animals' hoops in breeding farms, nature reserves, seas, and forest elements [36]. The rule in defining internet objects is everything that the internet can recognize through known internet protocols. In this case, the human is the beneficiary of all these harmony and objective communications. A person is also considered something as well if he/she has a specific internet address attached to him/her, such as a watch, glass, bracelet, electronic clothing, or medical equipment on or in the body.

IoT enables humans to control effectively objects near or far. Here are some selected examples of things that communicate online without direct human intervention. For example, a user can operate his car engine and control it from his smartwatch, or he can control the washing duties of his washing machine. In addition, he can identify the contents of the refrigerator remotely. Yet these are examples of the primitive form of IoT. The mature form goes to the direct communication between machine and machine directly. A few examples about that, the refrigerator can communicate with the shopping center to purchase and order supplies without human intervention. A specialist software in a car maintenance workshop can communicate remotely with a car to detect a defect within it without the need of visiting the workshop. A car can detect the edges, sidewalks, and signals in order to make decisions while driving or for lining up without driver intervention. A water evaporator can be released depending on a moisture and heat sensor at the atmospheric monitoring station. Our imagination could build many examples of IoT that could become a reality in our daily lives.

2.2 Gentelligent products

Product life cycle information is often required for product development and manufacturing in the supply chain. Thus, the application of lifecycle data retention for smart products provides new opportunities for information transfer to a new product generation and this technology is called gentelligent. Intelligent products are developed usually in research centers using gentelligent technology, which collects and stores information from products through their life cycle. Gentelligent technology starts

recording data during the manufacturing process. It sends the data online directly to storage units at the company server at specified intervals or retained on the device until the waste collection to be separated and then sent to the research center that is responsible for it. The method of sending information depends on the device type and the internet availability within it. This technology is a promising one for cyber-physical systems that contain analyzing side for enhancing the supply chain possesses.

Several requirements are to be considered for structuring the gentelligent components' system. Generally, the requirements are manufacturing, flexibility, environment, the best fit for technical inheritance information use, and the development description. The classification key of collected data is divided into two parts mainly [37]. The first part is common for all components of the current generation and the second part considers the individual information. From the first part, the single key digits are arranged and sorted so, that they consider the information from manufacturing and development phases and do not need to be changed during the time and proceeding life cycle. The second key part includes the usage phase, which can change during time and information related to the environment.

2.3 Radio frequency identification technology

Radio Frequency Identification (RFID) is continuously increasing its market share, taking the place of the traditional barcode technology, which supports the development of new applications, especially with using it as a powerful innovative gadget adopted in the development of IoT. This technology works on automatic identification by using specialized devices in the process of capturing signals emitted by RFID Tags, which is a very small piece that can take multiple forms. Two types of RFID technology are used, passive and active RFID systems. Passive RFID waits for a signal from an RFID reader. The reader sends energy, which converts that energy into an RF wave. Active RFID systems use battery-powered RFID tags that continuously transmit their own signal. RFID technology as an application in IoT has engaged in different manufacturing industry sections. Employing RFID systems as an IoT application has great importance in supply chain management as a valuable part of modern manufacturing and industrial automation. With the aid of using an RFID system, managers are able to track, monitor, and control their products in real-time from the status of being as raw material to the rotation as final products in shelves and warehouses. They have all the required data related to shipments, location, temperature, pressure, and time depending on the used sensors [36]. Moreover, in intelligent shopping by using RFID technology as an application of the IoT, the consumers can manage their time in daily life more efficiently, and they can save money. A real-time grocery list can be generated automatically for consumers and list the items that will be consumed or expired soon. Therefore, it prevents people to buy items that are not necessary and it will reduce waste. In addition, utilizing RFID as an IoT application by retailers will enable them to collect real-time data from their inventory, resources, and products next to have a better overview of their chain of customers and employees.

2.4 Cloud computing, fog computing, edge computing

Cloud computing term refers to the available on-demand computing resources and systems that provide several integrated computer services without local resources to facilitate user access. These services include data storage, backup and self-synchronization, software processing capabilities, task scheduling, e-mail payment, and remote printing. When the user is online, he/she can control these resources through a program interface that facilitates and ignores many internal

details and processes. Fog computing (or it is called fogging) is the structure that uses one or more clients or devices close to the user to complete a large amount of storage and communications next to management, configuration, measurement, and control instead of being stored as primary storage in the cloud data centers and internet. Both fog computing and cloud computing provide applications, storage, and data to end-users. Nevertheless, fog computing is close to end-users and more geographical distribution. On the other hand, edge computing (or it is called edge) has processes closer to the data source and does not need to be sent to a remote cloud or other centralized processing systems. By eliminating the distance and time that is used to send data to central sources, it improves the speed and performance of data transfer, in addition to devices and applications on the edge. For devices that are connected to the internet, the edge is where the device or the local network that contains the device is connected to the internet. For example, a user's computer or processor that is located within an IoT camera is considered the edge of the network, but the router of the user, internet service provider, or local edge server is also considered the edge. The important advantage is the network edge geographically close to the device, unlike cloud servers, which can be very far from the devices that are connected to.

Even with the differences in the three previous terms, they meet on replacing local resources with other internet-based participatory devices to save resources and energy. These applications are used at a corporate level locally or internationally, on a private server or within a wider scope within the internet, and individually or collectively.

2.5 Digital twinning

Digital Twins is the outcome of integrating IoT, software analysis, machine learning, and artificial intelligence with spatial network diagrams to create live digital simulation models that are changed and updated as their physical counterparts change. Digital twin continuously learns and updates by itself using several sources to keep real-time status. This learning system uses sensor data that transfers different aspects of the operating state. The cloned twin that is on a virtual platform is a digital form of the physical object. The essential utilize is to enhance business performance, by data analyzing and systems controlling to stop the possible problems and avoid stop working. Connectivity is one of the key characteristics of digital twinning technology. The recent development of IoT contributes to a few new upgrades into digital twinning technology. This technology authorizes the connection between the real component and its digital match; the basis of digital twins is defined on that. Without it, there will be no digital twin technology. This connection is created by sensors on the actual product that gets and integrates this data through various integration techniques. In addition to this, digital twin technology increases the connectivity between customers, products, and organizations.

The digital twin concept helps to reduce the production costs, since the products will be correct from the first run, and there are no demands for expensive physical tests or product/procedures updates. The digital twin technology is often predicting various outcomes supported by the information flow. With further programming and data analysis, digital twins can regularly control the IoT deployment to fulfill the highest level of efficiency. It also helps to understand how things would work before actually applying them.

3. Green supply chain applications within the industry 4.0 environment

Using industry 4.0 technologies supports reaching various applications within the green supply area that achieve sustainable results regarding saving time,

material, and energy. In the following, we will discuss five of the possible applications [1] that support building environment-friendly supply chains and would be adopted in cyber-physical systems.

3.1 Collection and transfer trucks

The trucks that collect garbage or transfer goods can be upgraded depending on the required tasks. Those trucks are defined either by size or by the type of transferred waste. The size can be important when the truck collects the waste from narrow alleys. Active RFID systems are useful to use on trucks to track their locations and active movements. Defining the truck's route by optimization algorithms is used. In the case of collecting garbage, the algorithms that create the routes of the collection trucks target the containers that give notification that the container is almost full until it is enough to fill the truck capacity. If there is still space, the containers that give less full notification are added to the route. If there is a container with a full notification, it means there is an urgent condition to empty it, within a short time. That reflects the flexibility of the system by creating the routes depending on the actual waste amount. There is no need to have the same routes every day in order, which means the ability to choose the shortest way for the truck next to not having full containers with garbage for a long time. This supports the protection of possible biological environment pollution. In addition, linking the work of the traffic lights and the trucks is possible to make the traffic lights changed into green light when the trucks are near. This connection would reflect positively on reducing GHG emissions by decreasing the truck waiting time at the traffic lights.

By taking into consideration the energy efficiency, developed optimization models using e-cars and e-bikes [38] are considered for city logistics supply chain operations. The research showed promising results for decreasing GHG emissions and consumed energy. Other researches also focused on garbage trucks [39] for validating the efficient model and evaluating its performance to increase the cost-efficiency and warrant environmental awareness of the waste collection process.

3.2 Smart containers

Many Industry 4.0 technologies could be applied to the containers both for garbage or goods containers. It is possible to install sensors that define the amount of waste/goods inside the container. The sensors would define more than one notification depending on the inner amount; for instance, when it is 50% full, 75% full, or 90% full. It is possible to install light alert, sound alert, or both to work with those notifications. Radio Frequency Identification (RFID) technology is a powerful innovative gadget, which would be used. By using active RFID systems, the containers send live data directly to the information collection system. On the other hand, active RFID systems are much more expensive than passive ones. It should be considered that there are different types of containers as well. In the case of the waste containers, they are defined depending on the waste types as organic and inorganic or as more specific targets, for instance, paper, glass, metal, or plastic. However, it is possible to use a smart container that can separate the inorganic waste by itself. This separation mechanism uses the relative relationship between the size and weight of the received waste since for each material; there is a specific density, next to the sound that appears when the waste is received. The sensors define the data (sound, size, and weight) of this received waste. Other mechanisms might be used as well, such as using IR (Infrared Radiation) or X-rays.

The collection containers are usually the first step of the collecting chain, which are in contact with the users. It is important to keep in mind that any change of the

collection procedures that should be done by the users should be essential, really needed, and would not be changed or at least, for a long time relatively. Because making different changes might confuse the users, and it costs a lot to make it clear and spread the right instruction about any the procedures to the users. Research studies [5] are working on using Industry 4.0 technologies to develop efficient waste containers within cyber-physical waste collection systems. Further development was researched [40] on a standard commercial waste bin. This dustbin was able to detect its current load, open-close the cover automatically, and remote access the load level using an online interface.

3.3 Data management

All the parts of cyber-physical systems should connect directly to data management using the internet. This management stores data and deals directly with all the system parts. Data about transportation, delivery time, collection trucks, and quantities in each part of the system, as well as the records of surveillance cameras (if they are used), are saved within this management. The used algorithms for creating routes of collection and transfer trucks are processed within this management as well. IoT enables the connectivity between the interconnected devices to make all the parts defined within the system to the management. The data management would use cloud-computing technology that refers to the computer resources available on-demand, which provides several integrated computer services without being restricted to local resources. In cases that require more privacy, private servers are used to store the received and processed data. If there is not enough more space in the servers, the new data will overwrite the oldest one.

On the other hand, data management provides creative solutions for raising sustainability and saving materials by counting on the connected users. Considering the users' kinds as individuals, workshops, factories, or companies, their Tender and taking possibilities are defined. For instance, a user (textile factory) has excessed textile materials. This user enters all the needed information on the platform (amount, type, and color). Any other interested user who finds the available materials can contact the offering user directly to get them. This proposed platform provides the possibility to use the excessed materials directly between the producers and reproducers. Moreover, it gives a space for creativity by finding out the available materials for upcycling and recycling that support sustainability without the need for extra transporting and treating steps.

3.4 Local composting

Composting is an effective way of the organic waste upcycling into compost to fertilize the plants. Local composting units are an effective environmental application that is possible to use. By disrupting them in appropriate locations that should be easy to access by local people, those units provide the possibility to the local people to directly fertilize their own organic waste like fruits, vegetables, dairy products, cereals, bread, coffee filters, eggshells, or meat. Generally, if the waste grew in a field or garden, it is relatively easy to compost it. Items such as red flesh, bones, and small amounts of paper are acceptable but take longer to degrade. Local composting would be connected to the data management so it would show the available space for waste until it is full and the needed time until completing the transformation into compost. When the compost is ready, it is used for the farms. However, there is a possibility to give back part or all of the resulted compost to the local community if they wanted. The participant users in filling the units should use ID cards to open the units and add their waste. Data management gives the

possibility to the users to register and make accounts for saving their waste sharing data and the required compost they want. The data management would inform the participant users about the compost collection amount and time details. The user should confirm his wanted share of the compost and he/she can use their ID card to collect the compost from the unit. The data management would arrange each person's share depending on the provided waste amount, the number of participants, and the actual need of the farms to receive the compost. By using local composting units, many advantages would be achieved.

3.5 Ecological footprint

The ecological footprint measures the amount necessary by nature to support humans or the economy. The calculations compare the required region for a biologically productive human consumption with a biologically productive region in the world. It is a measure of the human impact on the ecosystem of the planet, and it reveals the dependence of the human economy on natural capital. Therefore, it acts as a warning call for people and countries to monitor and regulate the activities that put the environment at risk, and if everyone notices their environmental footprint, there will be fewer environmental problems today, as problems such as carbon emissions, lack of clean air, increased desertification and global warming, and reduced environmental pollution. The available stored data within the data management allows making a direct application for the users reflects their attitude and lifestyle consequences. This could reflect on the whole supply chain positively on the environment by minimizing the direct demand of the last part of the chain. The users can select the used data types to measure their footprint depending on their preferences. The data comes from different resources directly such as the user's waste type and amount, the spent resources such as water and electricity, the daily purchased items, and the used transportation type. Data management analyzes and processes the collected numbers to reach suggestions and advice for the users to improve their selected options to raise sustainability and minimize the negative impact on the environment.

4. Results

4.1 Managerial and practical implication

The described research within this chapter aims to identify, clarify, and examine the possibilities and potentials of Industry 4.0 technologies on the green supply chain to enrich this area that is experiencing an increasing interest in both academic and industrial sectors.

The framework of this research can present a good answer for the reasonable possible questions of managers, coordinators, or stakeholders of the supply chain area such as:

- Should I consider upgrading my supply chain network using the new technologies?
- What are the possible upgrades that I can use?
- Is Industry 4.0 helping the supply chain to be greener and more sustainable?

Of course, those possible applications are to be tested and validated to ensure the anticipated results. However, those applications may have partly studied or

implemented, next to taking into consideration the flexibility and interchanging ability of the technologies depending on the desired results.

In practice, chapter 3 gives suggestions and recommendations for using the new technologies to raise the efficiency and productivity of the supply chain and waste management sectors considering the environmental and sustainable sides. Those suggested solutions should be considered fully or partly applied by the Research and development (R&D) departments depending on the business itself or to use them as bases for other suitable solutions that might support the positive impact on the environment by raising productivity or reducing the GHG emissions. The spread and development of Industry 4.0 are fast, and it should be considered to keep following those advancements to suit the target beachhead market.

4.2 Novelty

As it was researched within the systemic literature review, researching the Industry 4.0 topic has increased gradually in the last few years. The increasing number of the state of art Industry 4.0 applications in the different fields supports researching their effects and results. However, in the manner of green supply chain and applying Industry 4.0 technologies in the logistics and supply chain areas are yet to require more and more research as this research topic is still new and under development.

This chapter shows those applications simply and directly without addressing the complex technical details, which allows for non-IT specialists especially in the supply chains and sustainability sectors to consider those applications applied in reality. This work takes its importance from the diversity, variety, and richness of the application contents it has.

4.3 Future of digitalization of the green supply chain

It should be considered that digitalization in the green supply chain is inevitable, as so far, the newly developed technologies provide effective and direct environment-friendly solutions. Also, we cannot ignore the COVID-19 pandemic effect in accelerating the growth of supply chains that use the internet and cyber technologies. Considering that internet and online technologies that allow and facilitate remote control and orientation are the ground of Industry 4.0 tools, the digitalization of the green supply chain is going to grow fast in the short and medium terms for the next few years at least.

5. Conclusion

Industry 4.0 technologies provide interconnected applications that contribute directly to developing the green supply chain into cyber-physical systems that provide efficient performance in reducing GHG emissions, rising sustainability by increasing reliability, efficiency, and flexibility all along with saving energy and time next to protecting the environment. The transformation of conventional supply chain solutions into a cyber-physical green supply chain can be based on the above-described Internet of Things technologies and this transformation can lead to an improved, sustainable production, packaging, product sales, marketing, logistics, and product end-of-life management [41]. The authors presented the work of a few technologies within Industry 4.0 and discussed examples of the green supply chain within the industry 4.0 environment that support adopting the cyber-physical systems. Also, the anticipated results were presented as the managerial and practical implication and the future of digitalization of the green supply chain.

Conflict of interest

The authors declare no conflict of interest.

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References

[1] Akkad MZ, Bányai T. Applying Sustainable Logistics in Industry 4.0 Era. Lecture Notes in Mechanical Engineering. 2020;222-234 DOI: 10.1007/978-981-15-9529-5_19

[2] Rogers DS, Tibben-Lembke RS. Going Backwards: Reverse Logistics Trends and Practices. Logistics Executive Council: Pittsburgh, PA, USA; 1999.

[3] Ghosh, D, Sant, TG, Kuiti, MR, Swami, S. Shankar, R. Strategic decisions, competition and cost-sharing contract under industry 4.0 and environmental considerations. Resources, Conservation and Recycling. 2020;162:105057. DOI: 10.1016/j.resconrec.2020.105057

[4] Morella, P, Lambán, MP, Royo, J, Sánchez, JC, Corrales, LCN. Development of a new green indicator and its implementation in a cyber–physical system for a green supply chain. Sustainability (Switzerland). 2020;12(20):8629. DOI: 10.3390/su12208629

[5] Bag, S, Yadav, G, Wood, LC, Dhamija, P, Joshi, S. Industry 4.0 and the circular economy: Resource melioration in logistics. Resources Policy. 2020;68:101776. DOI 10.1016/j.resourpol.2020.101776

[6] Chauhan, A, Jakhar, SK, Chauhan, C. The interplay of circular economy with industry 4.0 enabled smart city drivers of healthcare waste disposal. Journal of Cleaner Production. 2021;279:123854. DOI: 10.1016/j.jclepro.2020.123854

[7] Dev, NK, Shankar, R, Swami, S. Diffusion of green products in industry 4.0: Reverse logistics issues during design of inventory and production planning system. International Journal of Production Economics. 2020;223:107519. DOI: 10.1016/j.ijpe.2019.107519

[8] de Man, JC, Strandhagen, JO. An Industry 4.0 research agenda for sustainable business models. Procedia CIRP. 2017;63:721-726. DOI: 10.1016/j.procir.2017.03.315

[9] Ramirez-Peña, M, Sotano, AJS, Pérez-Fernandez, V, Abad, FJ, Batista, M. Achieving a sustainable shipbuilding supply chain under I4.0 perspective. Journal of Cleaner Production. 2020;244:118789. DOI: 10.1016/j.jclepro.2019.118789

[10] Sharma, M, Kamble, S, Mani, V, Sehrawat, R, Belhadi, A, Sharma, V. Industry 4.0 adoption for sustainability in multi-tier manufacturing supply chain in emerging economies. Journal of Cleaner Production. 2021;281:125013. DOI: 10.1016/j.jclepro.2020.125013

[11] De Giovanni, P, Cariola, A. Process innovation through industry 4.0 technologies, lean practices and green supply chains. Research in Transportation Economics. 2020;00869. DOI: 10.1016/j.retrec.2020.100869

[12] Abideen, AZ, Mohamad, FB. Advancements in industrial supply chain through lean implementation - a review. International Journal of Logistics Systems and Management. 2021;38(1):45-64. DOI: 10.1504/IJLSM.2021.112426

[13] Sulistio, J, Alfatih, AB. The relation of Indonesia's strategic industry principles and Supply Chain Operations Reference (SCOR) Performance Attribute. IOP Conference Series: Materials Science and Engineering. 2019;528(1):012088. DOI: 10.1088/1757-899X/528/1/012088

[14] Cui HY, Huang ZX, Yuksel S, Dincer H. Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval

valued intuitionistic fuzzy decision approach. Renewable & Sustainable Energy Reviews. 2021;142:110844. DOI: 10.1016/j.rser.2021.110844

[15] Heydari J, Govindan K, Basiri Z. Balancing price and green quality in presence of consumer environmental awareness: a green supply chain coordination approach. International Journal of Production Research. 2021;59(7):1957-1975. DOI: 10.1080/00207543.2020.1771457

[16] Kumar S, Barman AG. Fuzzy TOPSIS and fuzzy VIKOR in selecting green suppliers for sponge iron and steel manufacturing. Soft Computing. 2021;25(8):6505-6525. DOI: 10.1007/s00500-021-05644-1

[17] Rahimi M, Hafezalkotob A, Asian S, Martinez L. Environmental Policy Making in Supply Chains under Ambiguity and Competition: A Fuzzy Stackelberg Game Approach. Sustainability. 2021;13(4):2367. DOI: 10.3390/su13042367

[18] Bhattacharya K, De SK. A robust two layer green supply chain modelling under performance based fuzzy game theoretic approach. Computers & Industrial Engineering. 2021;152:107005. DOI: 10.1016/j.cie.2020.107005

[19] Mejia C, Kajikawa Y. The Academic Landscapes of Manufacturing Enterprise Performance and Environmental Sustainability: A Study of Commonalities and Differences. International Journal of Environmental Research and Public Health. 2021;18(7):3370. DOI: 10.3390/ijerph18073370

[20] Yuan XG, Tang F, Zhang DL, Zhang XQ. Green Remanufacturer's Mixed Collection Channel Strategy Considering Enterprise's Environmental Responsibility and the Fairness Concern in Reverse Green Supply Chain. International Journal of Environmental Research and Public Health. 2021;18(7):3405. DOI: 10.3390/ijerph18073405

[21] Xia Q, Zhi BD, Wang XJ. The role of cross-shareholding in the green supply chain: Green contribution, power structure and coordination. International Journal of Production Economics. 2021;234:108037. DOI: 10.1016/j.ijpe.2021.108037

[22] Benzidia S, Makaoui N, Bentahar O. The impact of big data analytics and artificial intelligence on green supply chain process integration and hospital environmental performance. Technological Forecasting and Social Change. 2021;165:120557. DOI: 10.1016/j.techfore.2020.120557

[23] Pal B, Sarkar A. Optimal strategies of a dual-channel green supply chain with recycling under retailer promotional effort. Rairo-Operations Research. 2021;55(2):415-431. DOI: 10.1051/ro/2021016

[24] Gao JZ, Xiao ZD, Wei HX. Competition and coordination in a dual-channel green supply chain with an eco-label policy. Computers & Industrial Engineering. 2021;153:107057. DOI: 10.1016/j.cie.2020.107057

[25] Sherif SU, Asokan P, Sasikumar P, Mathiyazhagan K, Jerald J. Integrated optimization of transportation, inventory and vehicle routing with simultaneous pickup and delivery in two-echelon green supply chain network. Journal of Cleaner Production. 2021;287:125434. DOI: 10.1016/j.jclepro.2020.125434

[26] Hong SQ, Huang YJ. Relationship among Reverse Logistics, Corporate Image and Social Impact in Medical Device Industry. Revista de Cercetare Si Interventie Sociala. 2021;72:109-121. DOI: 10.33788/rcis.72.7

[27] Chen ZS, Wang HM. Inter-basin water transfer green supply chain coordination with partial backlogging under random precipitation. Journal of Water and Climate Change. 2021;12(1):296-310. DOI: 10.2166/wcc.2020.104

[28] Da BW, Liu CZ, Liu NN, Fan SD. Strategies of Two-Level Green Technology Investments for Coal Supply Chain under Different Dominant Modes. Sustainability. 2021;13(7):3643. DOI: 10.3390/su13073643

[29] Eid BM, Ibrahim NA. Recent developments in sustainable finishing of cellulosic textiles employing biotechnology. Journal of Cleaner Production. 2021;284:124701. DOI: 10.1016/j.jclepro.2020.124701

[30] Guo Y, Yen DA, Geng RQ, Azar G. Drivers of green cooperation between Chinese manufacturers and their customers: An empirical analysis. Industrial Marketing Management. 2021;93:137-146. DOI: 10.1016/j.indmarman.2021.01.004

[31] Sun Y, Yan H, Lu C, Bie R, Thomas P. A holistic approach to visualizing business models for the internet of things. Communications in Mobile Computing. 2012;1:1-7. DOI: 10.1186/2192-1121-1-4

[32] Illés B, Varga AK, Czap L. Logistics and Digitization. Lecture Notes in Mechanical Engineering.2018;220-225. DOI: doi. org/10.1007/978-3-319-75677-6_18

[33] Akkad MZ, Bányai T. Cyber-physical waste collection system: a logistics approach. In: Solutions for Sustainable Development: Proceedings of the 1st International Conference on Engineering Solutions for Sustainable Development (ICESSD 2019); London. United Kingdom: CRC Press; 2019.p.160-168 (2019). DOI: 10.1201/9780367824037

[34] Dobos P, Tamás P, Illés B, Balogh R. Application possibilities of the Big Data concept in Industry 4.0. IOP Conference Series: Materials Science and Engineering. 2018; 448;012011. DOI: 10.1088/1757-899X/448/1/012011

[35] Zhong RY, Xu X, Klotz E, Newman ST. Intelligent Manufacturing in the Context of Industry 4.0: A Review. Engineering. 2017;3:5:616-630. DOI: 10.1016/J.ENG.2017.05.015

[36] Azizi A. RFID Network Planning In: Azizi A, editors. Applications of Artificial Intelligence Techniques in Industry 4.0. Springer, Singapore 2018. p. 19-25. DOI: 10.1007/978-981-13-2640-0_3

[37] Lachmayer L, Mozgova I, Scheidel W. An Approach to describe Gentelligent Components in their Life Cycle. Procedia Technology. 2016;26:199-206. DOI: 10.1016/j.protcy.2016.08.027

[38] Akkad MZ, Bányai T. Multi-Objective Approach for Optimization of City Logistics Considering Energy Efficiency. Sustainability. 2020;12:18:7366. DOI: 10.3390/su12187366

[39] Bányai T, Tamás P, Illés B, Stankevičiūtė Ž, Bányai Á. Optimization of Municipal Waste Collection Routing: Impact of Industry 4.0 Technologies on Environmental Awareness and Sustainability. International Journal of Environmental Research and Public Health. 2019;16:4:634. DOI: 10.3390/ijerph16040634

[40] Cservenák Á, Bányai T. Smart bin development for cyber-physical waste collection. In: Proceedings of the 13th International Doctoral Students Workshop on Logistics; 16 June 2020; Magdeburg. Germany. Otto-von-Guericke University; 2020. p. 45-48

[41] Mathu K. Green Initiatives in Supply Chain Management Drives Enterprises' Competitiveness and Sustainability [Online First], IntechOpen, DOI: 10.5772/intechopen.94770. Available from: https://www.intechopen.com/online-first/green-initiatives-in-supply-chain-management-drives-enterprises-competitiveness-and-sustainability

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The integration of eco-friendly aspects, tools and solutions into a conventional supply chain leads to environmentally friendly global processes in the manufacturing and service industry. This book offers a selection of chapters that explain the impact of green supply chain solutions on value-making chains. The aim of this book is to help students at all levels as well as managers and researchers to understand and appreciate the concept, design and implementation of green supply chain solutions in the Industry 4.0 era.

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